INFORMEX: AN EXPERT SYSTEM TO ENHANCE INFORMATION PRESENTATION

By

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Bachelor of Science

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Stillwater, Oklahoma

1987

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF BUSINESS ADMINISTRATION
May, 1990

ABSTRACT

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Institution: Oklahoma State University

Location: Stillwater, Oklahoma

Title of Study: INFORMEX: AN EXPERT SYSTEM TO ENHANCE INFORMATION PRESENTATION

Pages in Study: 102 Candidate for the Degree of Master of Business Administration

Major Field: Management Information Systems

Scope and Method of Study: The proliferation of information systems in organizations has allowed companies to capture and store volumes of operational and strategic data. Unfortunately, most companies lack a systematic way to present this wealth of data into a form useful for decision makers. Artificial intelligence technologies provide a promising vehicle for improving this information flow dilemma. Scientists have conducted studies and experiments to find out how mode of information presentation (graph, table, etc.) and content (raw data, summarized, etc.) affects decision quality. Though much has been learned from this research, the findings have not been consolidated in a form that can be used by information systems professionals who create computer output. The objective of this research is to develop a knowledge-based expert system (knowledge system) for those who are charged with creating the delivery vehicle (report or graph) from the company's information system (i.e. system analysts). This project surveys twenty-nine experiments and integrates their findings in an expert system to recommend presentation format and content.

Findings and Conclusions: The INFORMEX expert system has 73 rules in its knowledge base. It uses information about the task type, task actions, task attributes, and individual characteristics to produce weighted recommendations for presentation format and content. The system also has a text-retrieval system with categorized summaries of the experiments used to build the knowledge base. This retrieval system provides an explanation facility for INFORMEX's recommendations. A second benefit of developing the knowledge base has been identifing areas where no or little research has been performed in the information presentation field.

ADVISER'S APPROVAL ______________________________

APPROVAL PAGE

INFORMEX: AN EXPERT SYSTEM TO

ENHANCE INFORMATION PRESENTATION

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CHAPTER I

INTRODUCTION

Organizations have recognized that quality information is a precursor for sound managerial decision making. They have addressed this need by developing elaborate information systems for management. For many managers, these systems produce either "too much" or "not enough" information [ChD74][Ack67][Vas77]. Some managers drown in voluminous output that adds little real value to their decision process, while other managers receive too few inputs or are given information in an inappropriate form which they cannot use.

Researchers have attempted to resolve this dilemma by investigating how information should be presented. Specifically, they have sought to identify the appropriate information presentation format and content for managerial decision makers. Much research by MIS professionals, management scientists, industrial engineers, and social scientists has tried to determine if more effective and efficient decisions are made when the task, presentation format, and individual characteristics are in concert.

Others have reviewed the empirical investigation of the presentation question: Dickson, Senn, and Chervany [DSC77] reported on nine experiments that used computer-based simulators. The article drew some broad insights from the survey of these experiments and presented some general implications for researchers and practitioners.

A broad literature review by Zmud [Zmu79] summarized the role of individual differences in MIS success. He concluded that individual differences are clearly a major force in the use of MIS, but was uncertain as to the relative importance of individual factors when contrasted with task and contextual considerations.

DeSancitis [DeS84] also surveyed the research literature and examined the empirical support for the premise that graphics are superior to tables. DeSanctis observed much contradiction among the studies and suggested that more careful attention to task, decision context, and subject background are needed in this area of research.

Jarvenpaa, Dickson, and DeSanctis [JDD85] reviewed the findings of and methodological problems with presentation format research. They argued for a framework approach to MIS research.

The objective of these reviews has often been to identify conceptual or methodological problems in the research or to support a particular directive for future work. While these reviews have been helpful in condensing a broad body of research, unfortunately they have not compiled the specific research findings in a form useful to those charged with driving a company's information system. The objective of this project is to develop an expert system to recommend information presentation format and content based on the results of empirical research.

Knowledged-Based Systems

Artificial intelligence (AI) differs from conventional computer programming methodologies in its ability to represent and solve problems symbolically, rather than numerically. Rule-based systems are a subfield of AI that attempts to represent knowledge and human expertise in rules or IF-THEN statements. While such rule-based systems are commonly known as expert systems, a distinction can be made between true expert systems and knowledge-based systems. Knowledge-based systems represent academic knowledge about a problem and contain limited heuristic abilities, while true expert systems incorporate extensive human expertise and intuition along with the academic knowledge [Rau88]. Rule-based systems have been heralded for their ability to "preserve and disseminate scarce expertise" [LMM86]. Many companies including Digital Equipment Corporation [BaO89] and Tektronix [SaT88] have documented successful uses of rule-based systems in this capacity.

Artificial Intelligence Applications in MIS

The popular and academic literature continues to document the increasingly broad application of knowledge-based and expert systems to many business problems. Unfortunately, few MIS departments, though often saddled with a multiple year application development/maintenance backlog, have mimicked this success in applying artificial intelligence to solve their own problems. In the relatively few documented cases of AI for MIS, increasing the MIS department's productivity has often been the primary objective. The traditional software development cycle has been indicted as a key factor in the MIS application development backlog [Sam87]. Recent projects have sought to use knowledge-based systems to aid in rapid prototyping of applications and to actually generate program code. One example is a research effort at IBM that created YES/L1, an AI tool that produces compilable PL/1 code [Rau88]. In an overview of commercial applications for software development, Rauch-Hindin [Rau88] recommends the use of AI in MIS development when the problem is logically complex, will require frequent application maintenance, or when applications must be custom tailored for multiple users or departments.

Hardware optimization and devising efficient search strategies for large or multiple data bases are other uses of knowledge systems for MIS. Boole & Babbage developed an expert system to optimize the use of Direct Access Storage Devices (DASD) in large computer centers [Rau88]. A collaborative effort between Stanford University, SRI International, and Exxon developed a knowledged-based interface to a data base about commercial shipping. The intelligent data base interface is able to drastically reduce the search and processing time required to answer user's queries.

While these applications are making the MIS department more productive in application development and processing, AI has not yet been applied to improve the quality and usability of the MIS output. INFORMEX is a knowledge-based system for the MIS department. It addresses the logically complex problem of presentation format and content selection and will be the knowledge vehicle for systems analysts and others who prepare the outputs from an information system.

Knowledge-based expert system technology has been successfully applied to a somewhat parallel problem in marketing. Rangaswamy, et al. [REB89] used a body of research literature and professional judgments to construct NEGOTEX, an international negotiations expert system. The system asks questions about the proposed negotiations, such as the nationalities of the negotiators, relative decision power, and desired outcomes, and makes recommendations about meeting location, negotiation strategy, and pre-meeting communication. The system has over 350 rules and has limited its focus to rules for American, Japanese, and Chinese negotiators.

The concept of using artificial intelligence technologies to recommend presentation format and content is a suitable domain for knowledge systems. The problem is semistructured with distinctly identifiable factors (individual, task, and presentation) that can be checked against known research findings (knowledge) to derive a recommendation. INFORMEX will serve as the dissemination vehicle for the body of knowledge that relates these factors.

Objectives

The objective of this research is to develop a knowledge-based expert system (knowledge system) for those who are charged with creating the delivery vehicle (report or graph) from the company's information system (i.e. system analysts). The knowledge system (INFORMEX) enquires about the target information system output (i.e., report or screen display), the individual decision maker characteristics (target user), and the type of task. Through the use of heuristic reasoning, INFORMEX compares these inputs to its knowledge base of research findings and heuristic "rules of thumb" to recommend a presentation format and information content. A sample INFORMEX recommendation might suggest vertically grouped bar charts, statistically summarized, and presented as a deviation from a standard value.

A second objective, a by-product of this effort, is to unify the results of what has been learned from previous experiments and to identify the gaps in our knowledge about information presentation.

CHAPTER II

KNOWLEDGE BASE FOR INFORMATION PRESENTATION

An axiom of computing holds that any system is only as good as the input that it receives, and expert systems are clearly no exception. The knowledge base represents the rules that the system will use to make its judgments, and the construction of an accurate knowledge base is the founding task of building expert systems. Edosomwan [Edo87] suggests that the first rule in constructing an expert system is to compile an accurate knowledge base from history, experience, and expert judgment that has been tested by thirty humans in an adequate environment with demonstrated successful results over a period of five years. In a relatively young research field, this luxury is not available nor can one all-knowing expert be interviewed. Therefore, documented experiments in academic journals served as the primary domain expert. Some of these experiments have been criticized for possible methodological flaws [JDD85] as well as inconclusive evidence [Hub83]. However, INFORMEX is not overly concerned with methodological problems, but rather

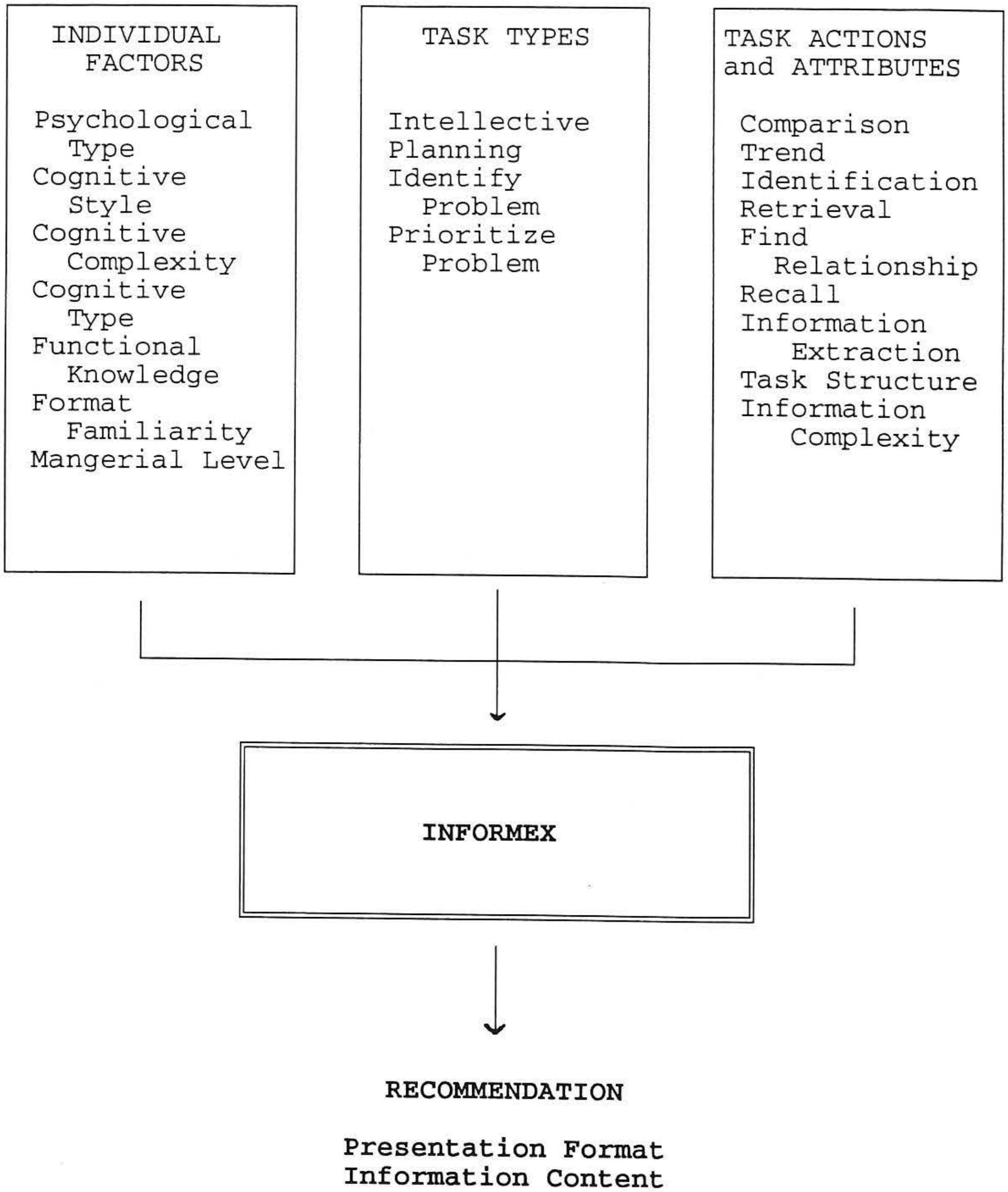

Figure 1. Conceptual Model

with the delivery and application of what has been learned from this research.

The second source of knowledge is professional judgments of information systems professionals and MIS faculty. The rules from these sources will receive a lower certainty rating in the knowledge base.

Figure 1 depicts the conceptual model for INFORMEX and shows how three research areas will be integrated to improve presentation format and content. The figure also lists the individual, task, and format variables that are incorporated in INFORMEX. Often these variables have been referred to in the literature by several names, so alternate names and example values have been included in the following section. Though this list is not exhaustive of every variable that has been studied with regard to the information presentation question, it represents the most frequently used variables and names for those variables in the literature that was reviewed.

Individual Variables

Research has identified some important cognitive variables about the information user.

Cognitive Complexity (field dependence/independence) has been used in many studies [BeD79][BaL77][Luc81][BeD85] and is described in the literature as Cognitive Style [OtD82], Individual Differences, and Personality Type [BeD85]. Individuals who are field independent perceive

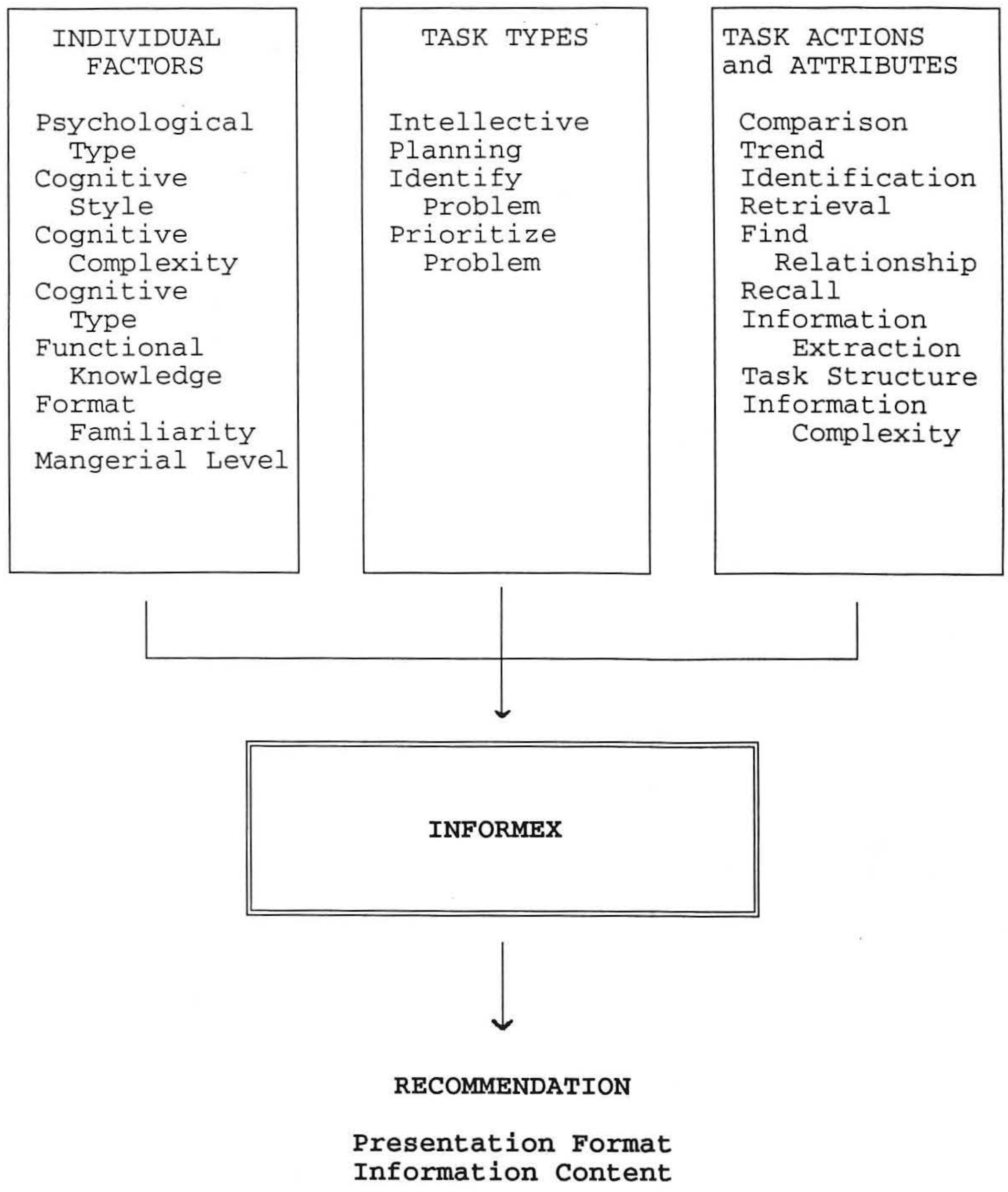

Figure 1. Conceptual Model

patterns of data largely independent of their context, while individuals who are field dependent perceive discrete items as embedded in their context [BaL77].

Cognitive Style (analytic/heuristic) has also received much attention as a cognitive variable [Vas77][LuN80]. This same measure has been referred to as Decision Style [Luc81] and Thinking Mode [BaL77]. Analytic individuals, sometimes called systematics, search for underlying causal relationships in the data that promote an algorithmic solution. Heuristic individuals search for analogies to familiar problems using intuition and trial and error rather than looking for causal relationships [Var77][BaL77].

Cognitive Type (sensing-thinking...intuitive-feeling) has been less frequently used as an individual typing measure [Dav81][Gha81]. The type is determined by using the Myers-Briggs typing instrument to measure perception and evaluation.

Psychological Type (high/low analytic) has pointed to valuable information about presentation format [BeS77] [BeD79[LuK79]. High analytic individuals approach a problem by structuring it in the framework of a planned problem solving method. Low analytic individuals tend to choose hypothesis testing and trial and error methods to solve the problem [BeD79].

Other individual variables include *Functional Knowledge* [LuN80], *Organizational Level* [BaL77], and *Quantitative*

Abilities [ZBM83], *Experience and Education* [Var77], and *Age* [ZBM83].

<u>Task</u>

While many of the instruments used to measure individual differences have been validated and cross-checked among studies, task classification and description has proven a most difficult area. Task is the principle determinant of information needs. Tasks differ by goals, criteria for completion, procedure to be followed, stress and time limits, and consequences of success or failure [DeG87]. Task environments can be described at several levels. They can be broadly classified by major task types, specific task actions, and descriptive task attributes.

Task types are the broadest classifications of task and imply the primary information gathering objective. Task types include "intellective," selection of an optimal alternative [DeG87], "planning," generating action-oriented plans; "problem identification," finding the problem, "problem prioritization," prioritizing multiple problems, and "information extraction," complex retrieval, comparison, and processing of information.

Task Actions are more descriptive of an individual's specific activities. Examples include "retrieval," retrieving a single value from a report; "comparison," systematic cross evaluation of multiple alternatives or attributes; "recall," the ability to later answer questions based on a prior exposure to information; and "find relationship" or "trend identification," finding an underlying relationship or trend in the data [GLR89].

Within these descriptions, tasks have also been categorized by task attributes such as complexity (number of variables and number of dimensions of information), environmental certainty, or structure of decision strategy [Pay82]-[JDD85][ZBM83][Jar89].

<u>Presentation Format</u>

Research dating back to 1927 has sought to identify the best information presentation format [CrS32][Was27]. The majority of studies have investigated the superiority of graphical versus tabular presentation methods [Des84], though some have specifically studied the value of differing specific graph types, i.e., pie, bar, and line charts [GLR89].

Though the characteristics and merits of each graphical format can be described in many ways, a classification scheme allows a level of abstraction across many graph types. Bertin [Ber83] developed an implantation construct for classifying graphs based on their primary perceptual element. According to this construct, the primary perceptual element for scatter plot and dot graphs is a point; for bar, column, bubble, area, pie, and star graphs is an area; and for line, segmented bar, and 3-D graphs is a line [GLR89].

Other researchers have worked to better understand the appropriate content for information presentation. Raw data versus statistically summarized, exception reporting, and level of aggregation have been important content topics [BeS77][Luk79][OtD82].

Empirical Findings by Task Type

As researchers began designing experiments to understand the role of presentation mode and information content, most of the earlier experiments focused on the individual variables and presentation formats. Confounded by conflicting results, the decision making task environment surfaced as a key determinant of presentation format and content.

The following experiments are grouped by the primary task type(s) and/or task action(s) studied. They are classified based on the description of the experimental task reported in the literature. Since task has proven such a difficult area to classify, few of the studies agreed on any vocabulary to describe the experimental task. When an author clearly identified the principle task type and/or task actions used, we assigned the terms described in the previous section. However, in some of the studies, the task type and/or task action was not clearly explained. The task categories were inferred from the experimental context for these studies. Table I lists the studies chronologically and categorizes them by task, individual, presentation, and

TABLE I

CHRONOLOGICAL LITERATURE CLASSIFICATION AND SUMMARY

STUDY	INDEPENDENT VARIABLES: TASK ENVIRONMENT	INDEPENDENT VARIABLES: INDIVIDUAL	INDEPENDENT VARIABLES: FORMAT & CONTENT	DEPENDENT VARIABLES	MAJOR FINDINGS
Washburne (1927)	comparison recall retrieval (intellective)		narrative, table, line, bar, pictogram	accuracy	presentation form significantly affects understanding; complexity does not determine format effectiveness; quantity of data and arrangement affect recall; for complex static comparisons, bar chart; for simple, static comparisons, pictograph; for dynamic comparisons, linegraph; for specific amounts, statistical table
Croxton & Stein (1932)	comparison (intellective)		bars, squares, circles, and cubes	accuracy	bar charts showed highest interpretation accuracy; squares and circles were more accurate than cubes; centered or drawn at baseline was not significant
Chervany & Dickson (1974)	intellective (simple retrieval) (find relationship)		tabular formats of either raw data or statistically summarized	decision time, performance (cost), confidence	statistically summarized group had lower costs, took longer, had lower decision variance, more decision confidence variance, and appeared to focus on the key problem
Bariff & Lusk (1977)	preference survey	psychological type, organizational level	raw v. statistically transformed, tabular v. graphical	readability, completeness, ability to locate abstract data, amount of detail	prefer disaggregated raw data; psychological profiles were uniquely identified with an organizational level;
Benbasat & Schroeder (1977)	intellective (comparison) (identify trend)	psychological type, high/low functional knowledge	tabular v. graphical (statistically summarized), exception reporting, number of reports available	performance (cost), decision making time, number of reports requested	graphical format users had lower decision costs; both high functional knowledge and graphical groups requested fewer reports; overload group requested most reports
Vasarhelyi, 1977	planning (identify trend)	cognitive style, education, experience	tabular	performance, (judged by panel), decision time	cognitive factors were linked to performance, types of information used, and decision time
Zmud (1978)	preference survey		table, bar chart, graph	identifying dimensions of information; format ratings by dimensions	graph had best rating on six of the dimensions; bar chart was least preferred in all categories; tabular & graph had equal ratings in accuracy; tabular preferred
Benbasat & Dexter (1979)	intellective (identify trend) (retrieval) (find relationship)	psychological type	tabular database inquiry v. structured/aggregate reports	profit, decision time, number of reports requested	low analytics with aggregate reports had poorest performance and requested more reports

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Lusk & Kersnick (1979)	retrieval (comparison)	psychological type	raw data, tabular percentage, histogram of raw data, cumulative frequency graphic of raw data, cumulative frequency graphic of percentages	perceived complexity accuracy	high analytics outperformed low analytics on all report types; task performance decreased as report complexity increased; report format and psychological type affect task performance
Lucas & Nielsen (1980)	intellective (retrieval) (find relationship)	cognitive style, age, work/military experience	tabular v. graphical, hardcopy v. crt	profit, learning	additional information supports greater learning was not supported; crt's superior; graphics as a superior mode was not supported; individual differences were highly significant
Davis (1981)	intellective (retrieval) (find relationship)	cognitive type	tabular v. graphical; raw v. statistically summarized	cost of production, decision time, level of confidence	graphical-raw for sensing-thinking; tabular-raw or summarized for sensing-feeling; tabular-raw or graphical-summarized for intuitive-feeling; any type for intuitive-thinking
Ghani (1981)	intellective (retrieval) (find relationship)	cognitive type	volume of information, tabular v. graphical	profits, decision time, user format preferences	users are likely to oppose a change in presentation format, graphics superior to tables was not supported, some indications that cognitive type can be linked to presentation format
Lucas (1981)	intellective (identify problem) (retrieval) (find relationship)	cognitive style	tabular hardcopy, tabular crt, statistical graph, combined statistical, graphical simulation, combined simulation	performance, information usefulness, understanding	hardcopy performed better than CRT; graphical performance not shown to be superior to tables, except graphical group gained better understanding; cognitive style is significant
Geiselman & Samet (1982)	recall retrieval (intellective)		fixed v. personalized format	objective test scores, average number of notes written, test score divided by number of notes	personalized format group did not score higher than fixed group on objective test, fixed group recorded more notes, personalized group retained more from reports while fixed group from notes
Otely & Dias (1982)	identify problem intellective (find relationship) task complexity	cognitive complexity	4 levels of aggregation, tabular	performance (percentage error deviated from actual inputs), decision time	level of aggregation was highly significant; aggregation improved performance to a point then caused a decline; cognitive complexity was not significant; performance varied by task complexity

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Watson & Driver (1983)	recall		tabular v. three dimensional graphical	immediate recall, delayed recall	three dimensional graphics were not superior in immediate nor delayed recall
Zmud, Blocher, & Moffie (1983)	intellective task complexity	cognitive complexity, age, experience, quantitative abilities	black & white tabular v. color bar chart	accuracy, learning	color graphic most accurate for low task complexity, but least accurate for high task complexity; high quantitative scores performed better with tables; demographic attributes more associated with decision confidence while cognitive skills more associated with accuracy
Remus (1984)	intellective (retrieval) (find relationship)		tabular v. graphical	decision costs	results favor tabular, but were not statistically significant; error reduction technique increased support for tables
Benbasat & Dexter (1985)	intellective (retrieval) (find relationship)	cognitive complexity	mono and multi-colored tabular and graphical	profit, decision time, report attribute ratings	multi-colored had higher profits, more understandable; significant interaction between color and cognitive complexity
Davis, Larry (1985)	information extraction (retrieval) (comparison)		tables, line graphs, bar charts, pie charts	decision time, accuracy	tables are much faster for simple retrieval, line and bar are best for retrieval and comparison, tables are most accurate for intense comparison
Jarvenpaa, Dickson, & Desanctis (1985)	identify problem task complexity		simple bar charts, grouped bar charts	decision performance, interpretation accuracy, user satisfaction, and decision confidence	inconclusive, problems with task complexity rating
Dickson, DeSanctis, & McBride (1986) 3 Experiments	1) intellective, (comparison)(retrie val); low complexity, 1 variable 2) intellective, (identify trend), (retrieval), (comparison); more complex, 2 variables 3) intellective, recall, (abstrac-tion), (retrieval); complex, multiple variables		1) bar charts v. tabular 2) line plots v. tabular 3) graphical v. tabular, volume of information,	interpretation accuracy, decision quality	1) no significant differences between graphical and tabular 2) graphical outperformed tabular and perceived the task to be easier 3) graphical better with a large amount of material, tabular better with smaller chunks of information

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Goslar, Green, & Hughes (1986)	planning		data level (volume)	number of alternatives considered, decision time, decision confidence, amount of data considered, decision strategy, performance	data level did not affect decision maker confidence, strategy, or performance
Lauer (1987)	extract info (complex retrieval) (comparison)		line, simple & grouped bar, pie, and tabular formats, eight levels of information complexity	performance time, accuracy	line graphs least accurate, tables most accurate; pie charts least sensitive the increases in information complexity, tables most effective for estimating differences
Remus (1987)	intellective (retrieval) (find relationship)		tabular v. graphical	decision costs	no significant difference in actual costs between display types; tabular displays better in low complexity environments; graphical better in environments of intermediate complexity
Dos Santos & Bariff (1988)	intellective identify problem prioritize problem (find relationship)		exception v. variable report content, actual v. difference from base case	problem identification, problem prioritization	changes from a base case performed better than actual values; exception reporting was not superior to variables
Umanath & Scamell (1988)	recall identify trend find relationship (intellective)		tabular v. bar chart	1) recall of directional order, pattern recall, and specific fact recall 2) pattern integration and specific fact recall	1) graphical superior for recall of directional order and pattern 2) graphical more effective for integrative pattern recall; simple specific recall was indifferent to format
Gillan, Lewis, & Rudisill (1989)	retrieval comparison (intellective)		17 types of graphs: including scatter plots, line, bar; perceptual complexity, figure-to-axis relation, informational complexity	speed, accuracy	subjects respond faster and more accurately on comparison than on identification
Jarvenpaa (1989)	intellective structured decision strategies		horizontal bar chart, grouped horizontal bar chart	acquisition direction, evaluation direction, decision time, decision quality	presentation format strongly influences decision processes, sequence of information acquisition; format influences decision process more than task demands; grouped bar chart elicited processing by attribute rather than alternative

dependent measure variables. These experiments were selected because of their inclusion in one of the major literature review papers in this field [DSC77][Zmu78][Hub83][Des84], recent publication, or unique contribution to the field.

Intellective

The intellective task type is clearly the most investigated description of task. Though few researchers have used the term intellective, the tasks described in these experiments had a quantitatively optimal or relatively more optimal solution. Most experiments involved a production operations management scenario where the subjects had to derive or forecast an inventory level or order quantity. Other experiments involved a classification or pattern recognition type of question.

Chervany and Dickson [ChD74] compared tabular presentations of statistically summarized and raw data. They found that the group receiving statistically summarized information had lower decision costs, less decision variance, and focused on the key factor of the problem, though the group did not seem to realize that they had found the key factor. This group also took longer to make decisions and showed much more decision confidence variance than the raw data group.

Benbasat and Schroeder [BeS77] compared tabular versus graphical displays and controlled for psychological type and functional knowledge. The graphical report group had six percent lower costs and requested fewer reports than the tabular group. Psychological type and functional knowledge did not statistically affect decision cost or decision making time.

Benbasat and Dexter [BeD79] used tabular output to compare structured/aggregate report content with user-defined data base inquiry report content. They also controlled for psychological type and found no profit performance differences between the report content treatment groups. The high analytic group performed better with the structured/aggregate reports while the low analytics performed better with disaggregated reports. The low analytics were deemed better suited to the database inquiry report content.

Lucas and Nielsen [LuN80] analyzed graphical versus tabular displays and hardcopy versus CRTs. They found that the CRT groups performed better than the hardcopy groups. The experiment controlled for cognitive style, age, and work experience. Though inconclusive, they also suggest that individual background differences do affect the way users respond to different presentation modes.

Davis [Dav81] controlled for cognitive type and investigated tabular versus graphical presentation modes and statistically summarized versus raw data report content. He suggests that if the user's cognitive type is unknown, the report should be either graphical or tabular raw data. Sensing-thinking types should use graphical raw data while sensing-feeling users perform equally well with either tabular format. Intuitive-feeling types had the best performance using tabular raw data or statistically summarized graphs. Intuitive-thinking types did not appear well suited to production operations tasks.

Ghani [Gha81] tested tabular versus graphical displays and volume of information. Midway through the experiment, the format and volume of information was changed for some users. He found that users are likely to show a strong preference for familiar formats and oppose a change in presentation format. After a change in either presentation format or volume, user performance can be expected to initially deteriorate. Graphical reports were not shown to be superior to tables and actually led to poorer performance. On the basis of cognitive type, the study suggests that feeling types will perform better with and prefer graphs while sensing types achieve the same performance with tabular formats. Generally, tasks that require simple retrieval should use tabular formats while tasks that require perception of relationships among the data should use graphical representations.

Lucas [Luc81] used six combinations of tabular, graphical, statistical, and simulation format and content presentations to measure user's performance, understanding of the problem, and information usefulness. The study also controlled for cognitive type and found that non-graphical hardcopy groups performed better than CRT groups. The graphical groups gained a better understanding of the problem, and the heuristics with graphical output performed better with the simulation and frequency distribution report content than did the analytics. The results further suggest that analytics may have a preconceived model in mind and simply use the reports to confirm or disprove their model. Heuristics do not have a preconceived model and benefit more from a visual representation of the information.

Zmud, Bocher, and Moffie [ZBM83] compared black and white tabular reports with color bar charts while controlling for task complexity, cognitive complexity, age, functional experience, and quantitative abilities. The study revealed that color graphic reports had the highest accuracy for low task complexity, and the lowest accuracy for high task complexity. More experienced subjects expressed more confidence with graphs while users with higher quantitative scores performed better with tables. Presentation format differences were stronger than individual factors.

Remus [Reu84] tested the merits of tabular versus graphical displays over a twenty-four period and found that inconsistent decision making can offset the benefits of a presentation format. Though the study found no advantage for either presentation format based on the user's decisions, the tabular displays did yield lower decision costs when consistent, composite decision rules were applied. A second study [Reu87] further confirmed these findings.

Benbasat and Dexter [BeD85] studied both mono- and multi-colored reports and tabular versus graphical presentation formats. The multi-color group performed better than the mono-color group. Although neither tables nor graphs were deemed clearly superior, the cognitive complexity measure did give some guidance in selecting presentation format. Field-dependents with mono-color reports had the worst performance while field-dependents with color reports performed substantially better than field-independents with mono-color reports. Other insights from the study suggest that graphical reports were perceived to be more relevant for decision making and multi-color reports were thought to more clearly identify when good decisions were being made. The tabular reports were perceived to be more accurate and given the highest understandability rating by field-dependents.

Dos Santos and Bariff [DoB88] studied two levels of report content. They looked at exception-based versus variable-based selection of information and change from a base case versus actual outcomes. The users performed much better when the reports were presented as a change from a base case. Exception based reports hindered problem identification.

Jarvenpaa [Jar89] analyzed implications of simple horizontal and grouped horizontal bar charts on data acquisition and evaluation direction. Acquisition direction was found to be a function of the graphical format, not of the congruence between the format and task, and evaluation direction was influenced by the congruence between the demands of the task and the graphical format. The way that graphical information is arranged on a display affects the order in which users acquire information and users will adjust their decision time, rather than accuracy, when the task demands and format are incongruent. Grouped bar charts tended to elicit attribute processing.

Planning

The following studies were constructed around an unstructured problem that did not have a quantitatively identifiable optimal solution.

Vasarhelyi [Vas77] used a balanced (equally qualitative and quantitative) planning task and controlled for cognitive style. The study found that heuristics utilized less information, used more qualitative and less quantitative information, and made decisions more quickly than analytics. Both analytics and heuristics performed equally well in a balanced planning situation.

Dickson, DeSanctis, and McBride [DDM86], in the second of the three reported experiments, used a three period forecasting problem as the task context. Half of the subjects received historical information in line graphs while the other half received tables. The graphical group outperformed the tabular group in decision quality and perceived the task to be easier.

Goslar, Green, and Hughes [GGH86] built their study around an ill-structured marketing problem. Three groups received insufficient, sufficient, and overload volumes of data about the problem in a tabular format. The experimenters found that volume of information did not significantly affect decision maker confidence, performance, decision time, or the decision making process. The users that received the low volume of information indicated a greater understanding of the alternatives and the impact of these alternatives. The authors also reported that under limited decision time, users tend to accentuate negative information more than supporting information.

<u>Problem Identification</u>

The problem identification task focuses on finding the real problem more than solving the problem. It could imply using any of the described task actions (comparison, find relationship, etc.)

Otely and Dias [OtD82] used a production environment to measure problem identification abilities. The users were controlled for cognitive complexity and received tabular output representing four levels of aggregation. They concluded that increasing aggregation caused performance to improve up to a point and then to decline (inverted U shape) and aggregation that reduces the amount of information without changing its content improves performance while aggregation that reduces both volume and content is detrimental to performance. Cognitive complexity was not significant.

Jarvenpaa, Dickson, and Desanctis [JDD85] used simple and grouped bar chart in an unstructured marketing case with three levels of task complexity. The experimenters themselves identified problems with the complexity measure and conducted two follow up experiments that give insight for methodological design. The study weakly suggests that grouped bar charts are superior to simple bar charts for a low complexity task.

Information Extraction

The information extraction task could also be described as complex retrieval. It implies the task actions of identification, comparison, estimation, and retrieval [Dav85][Lau87].

Davis [Dav85] used an information extraction task to evaluate bar charts, pie charts, line graphs, and tables. The questions varied in complexity and performance was measured by time and accuracy. Davis found that tables yielded much better time performance for a simple retrieval task and the best accuracy for an intensively comparison task. Line and bar charts had the best accuracy when both retrieval and comparison are part of the task. Pie charts yielded the best accuracy but slowest performance for a task that requires estimates, scans, identifications, and comparisons.

Lauer [Lau87] used line graph, simple and grouped bar charts, pie chart, and tabular formats to evaluate the information extraction task. Information complexity was varied over eight levels. Pie charts were the only tested format shown relatively insensitive to increases in information complexity. The users were the least accurate with line graphs and the most accurate with tables. Tables required less time than any of the graphical formats and were the most effective when estimating differences. Bar charts and line charts yielded the best performance when identifying highest or lowest values.

Empirical Findings by Task Action

The following studies examined a task action and are more micro focused and less generalizable than the studies based on a task type.

<u>Comparison</u>

Washburne [Was27] evaluated fifteen presentation formats including narrative, table, line, bar, and pictograph representations of the same information. For the comparison questions, the study showed that bar charts are best for complex, static comparisons (requiring many comparisons) while pictographs are recommended for simple, static comparisons. Line graphs are recommended to depict dynamic comparisons (net change) and pictographs are effective for very simple data, but a poor choice for complex data.

Croxton and Stein [CrS32] asked users to compare two like shapes of bars, squares, circles, and cubes that differed in size. They found that user's estimates based on bars were more accurate than any of the other formats and estimates based on squares were clearly better than those based on cubes. Whether the shapes were drawn at baseline or vertically centered was not significant.

Gillan, Douglas, and Lewis [GLR89] tested a comparison and retrieval task against seventeen graphical formats classified by their primary perceptual element of point, line, or area. The users responded faster and more accurately to comparison rather than retrieval tasks, and comparative judgments were made from the graphs without first translating the representations to values. Primary perceptual elements (area, line, point) were more significant with the comparison task, and graphs based on area produced the fastest and most accurate performance.

Recall

The Washburne [Was27] study also evaluated recall. It found that the quantity and arrangement of data do significantly affect recall. Logical arrangement is important in respect to recalling relative amounts and visual pattern is important when recalling specific amounts.

Geiselman and Samet [GeS82] studied a fixed versus personalized format for brief exposure to tabular information. The users were allowed to record notes under very strict time limitations. The personalized format group did not show higher overall objective test scores than the fixed format group. The personalized group wrote down fewer notes than the fixed format group and appeared to have learned more from viewing the information, rather than the notes.

Watson and Driver [WaD83] tested the effectiveness of three dimensional computer graphics versus tabular representations on immediate and delayed recall. Neither format was shown to be superior for either immediate or delayed recall.

Umanath and Scamell [UmS88] divided the recall task into recall of directional order (trend), pattern, specific fact, and pattern integration. Both bar charts and tables were evaluated and the graphical format was found superior for the recall of directional order, pattern, and pattern integration. Specific fact recall was indifferent to format.

Retrieval

The Washburne [Was27] study described earlier recommends statistical tables for specific value retrieval.

Lusk and Kersnick [LuK79] examined five presentation formats: raw data, tabular percentage transformation, histogram of raw data, cumulative frequency graphic of raw data, and cumulative frequency graphic of percentages. The users were asked to simply retrieve or retrieve and perform minor computations from the five presentation format/contents and were also controlled for psychological type. The study found that the tabular report group was perceived to represent a lesser degree of complexity than the graphical group and resulted in better performance. The high analytics performed better than the low analytics on all presentation formats.

Gillan, Lewis, and Rudisill [GLR89] also found that informational complexity had a strong effect on performance with a retrieval task. Subject response accuracy declined rapidly as information complexity was increased.

Unclassified Tasks

Bariff and Lusk [BaL77] conducted a field study where supervisors and administrators from a community nursing service evaluated three report sets for readability, completeness of data, simple retrieval and abstraction of data, and volume of detail. The study suggested that users of both psychological types prefer disaggregated raw data.

Zmud [Zmu78] sought to identify the relative importance of various dimensions of information based on user ratings. No performance measures were incorporated in the study. Tables, bar charts, and a graphical format were evaluated yielding four dimensions of information: quality of information, relevancy components (accurate, factual, quantity, reliability/timeliness), quality of format (arrangement, readability), and quality of meaning (reasonableness). The graphical format received the highest overall rating with the bar charts receiving the lowest. Tabular and graphical formats had equal ratings in accuracy.

Analysis of Empirical Studies

Table II summarizes the number of studies by task and cognitive variables. The Focused Studies column totals are the number of studies that specifically stated the task types or task actions that were studied, while the Total column also includes the task classifications that were implied from the experimental context. Clearly, the intellective task is the most frequently investigated experimental task. The most likely reason for this frequency is that subject performance on quantitative problems is more easily evaluated in a laboratory setting than the other tasks. Studies that used a planning or problem identification task often reported problems in calibrating the difficulty of the task [JDD85]. The experimental attention to task actions is more distributed.

CROSS COMPARISON OF TASK AND COGNITIVE FACTOR STUDIES
TABLE II

TASK TYPES:	No Cognitive	Cognitive Complexity	Cognitive Style	Cognitive Type	Psychological Type	FOCUSED STUDIES	TOTAL EXPERIMENTS
Intellective	14	3	1	2	2	17	22
Planning	2		1			3	3
Problem Identification	2	1	1			3	4
Problem Prioritization	1					1	1
Information Extraction	1					1	1
TASK ACTIONS:							
Comparison	5				2	3	7
Retrieval	10	1	2	2	2	4	17
Recall	5					5	5
Find Relationship	5	2	2	2	1	1	12
Identify Trend	3		1		2	1	6
Unclassified Task	1				1		2
TOTAL EXPERIMENTS	49	7	8	6	10	39	[1]80

[1]Though most studies focused on only one task type, multiple task actions were often evaluated in one study.

Table II also summarizes the number of studies by cognitive and individual factors. The four cognitive factors have received approximately equal experimental attention in these studies. The other individual variables previously described (functional knowledge, organizational level, etc.) were usually unique to only one experiment. Experience/education is an exception that was used in three experiments.

Limitations of the Knowledge Base

Only ten of the twenty-nine studies listed in Table I have incorporated a given task, individual factors, and presentation format/content variables in the experimental design. Table II shows a cross tabulation of the number of studies incorporating both a task and cognitive factor in the experiment. The four cognitive factors have received equal attention with the intellective task, but virtually no consideration among the other task types or even any of the task actions.

CHAPTER III

DEVELOPMENT OF THE KNOWLEDGE BASE

Each of the reviewed empirical studies was summarized in a short text document. They were categorized by the types of variables (task, individual, format and content) that were operationalized in the study and the findings of the study. These summaries provide the body of the explanation facility for INFORMEX's conclusions and are included in Appendix A.

Because of the great diversity of terminology and research designs used in the literature, extracting rules from the studies proved to be a formidable task. Consistency in terminology had to be developed between the studies'variables and findings. After several unsuccessful attempts at extracting rules, a rule worksheet was successfully developed to help standardize the terminology.

The worksheet was developed by listing all of the types of variables and attribute values that had been included in any study. This list was refined to include the more frequently used variables and attribute values. A sample worksheet is shown in Figure 2. Each study was reviewed

TASK (1) TYPE	TASK (1) ACTIONS	PSYCHOLOGICAL TYPE	COGNITIVE STYLE	COGNITIVE TYPE	COMPLEXITY
Intellective	Comparison	High Analytic	Analytic	Sensing-Thinking	Field Dependent
Planning	Trend Identification	Low Analytic	Heuristic	Sensing-Feeling	Field Independent
Training	Simple Retrieval			Inutitive-Thinking	
Problem Identification	Find Relationships			Intuitive-Feeling	
Problem Prioritization	Recall				
	Information Extraction				

FUNCTIONAL (1) KNOWLEDGE	RESPONSE (.5) TIME	RETENTION (.5) REQUIREMENTS	INFORMATION (1) COMPLEXITY	TASK (1) STRUCTURE
High	Important	Important	1 Variable	Structured
Medium	Not Important	Not Important	2 Variables	User-Defined
Low			More Than Two	

USER FAMILIARITY (.5) WITH FORMAT	USER FAMILIARITY (.5) WITH CONTENT	TABULAR	GRAPHICAL	SPECIFIC FORMAT	REPORT CONTENT
Tabular	Change from Base Case	Yes	Yes	Grouped Bar	Change from Base Case
Graphical	Exception from a Standard	No	No	Column	Exception from a Standard
Grouped Bar	Raw Data			Pie	Raw Data
Column	Statistical Transformation			Star	Statistical Transformation
Pie				Area	
Star				Line	
Area				Segmented Bar	
Line				Three-D	
Segmented Bar				Scatter Plot	
Three-D				Simple Bar	
Scatter Plot				Bubble	
Simple Bar					
Bubble					

RULE PRIORITY: 1 2 3 4 5 6 7 8 9 10

CERTAINTY: .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

Figure 2. Sample Rule Worksheet

TASK (1) TYPE	TASK (1) ACTIONS	PSYCHOLOGICAL TYPE	---- COGNITIVE ----		COMPLEXITY
			STYLE	TYPE	
Intellective	Comparison	High Analytic	Analytic	Sensing-Thinking	Field Dependent
Planning	Trend Identification	Low Analytic	Heuristic	Sensing-Feeling	Field Independent
Training	Simple Retrieval			Inutitive-Thinking	
Problem Identification	Find Relationships			Intuitive-Feeling	
Problem Prioritization	Recall				
	Information Extraction				

FUNCTIONAL (1) KNOWLEDGE	RESPONSE (.5) TIME	RETENTION (.5) REQUIREMENTS	INFORMATION (1) COMPLEXITY	TASK (1) STRUCTURE
High	Important	Important	1 Variable	Structured
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USER FAMILIARITY (.5) WITH FORMAT	USER FAMILIARITY (.5) WITH CONTENT	TABULAR	GRAPHICAL	SPECIFIC FORMAT	REPORT CONTENT
Tabular	Change from Base Case	Yes	Yes	Grouped Bar	Change from Base Case
Graphical	Exception from a Standard	No	No	Column	Exception from a Standard
Grouped Bar	Raw Data			Pie	Raw Data
Column	Statistical Transformation			Star	Statistical Transformation
Pie				Area	
Star				Line	
Area				Segmented Bar	
Line				Three-D	
Segmented Bar				Scatter Plot	
Three-D				Simple Bar	
Scatter Plot				Bubble	
Simple Bar					
Bubble					

RULE PRIORITY: 1 2 3 4 5 6 7 8 9 10

CERTAINTY: .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

Figure 2. Sample Rule Worksheet

again and the appropriate attribute variables were circled on the worksheet to form a rule. For example,a study might include an intellective task requiring a decision maker to consider two variables and compare several alternatives. Each of these would be circled on the rule worksheet along with the experimental findings. If the study found that high analytics performed better with tabular raw data, these results would be circled in the recommendation section of the rule worksheet. A second rule with the same independent variables (intellective, 2 variables, etc.) would be recorded if the study also concluded that low analytics performed better with statistically transformed graphs. A separate worksheet was completed for each rule.

Since expert systems also allow rules to be prioritized and weighted for certainty, each rule has been ranked based on the following criteria. Higher priorities were assigned to rules with more methodological richness, which we defined as the explicit inclusion of more categories of variables. The finding from a study that investigated a planning task type, specified comparison and recall task actions, and qualified the users by cognitive complexity and level of functional knowledge would receive a higher priority than a finding where only the task was identified and no individual measures were used. These priorities were scored from 1 to 10 based on the weights noted in parenthesis in Figure 2. The certainty of a rule's conclusion is based on the statistical significance of the experimental results. Findings that were significant at the .01 level received a certainty rating of 1. Those significant at .05 received a .7 rating and the finding that only supported directionalities received a .5.

When the description of the experimental environment or the results in the paper were difficult to interpret, more than one person independently reviewed the study and independently completed rule worksheets. These sheets were then discussed and combined into the production rule set. Appendix B contains a complete listing of the knowledge base.

CHAPTER IV

FUNCTIONAL DESCRIPTION OF INFORMEX

Scope

The INFORMEX prototype is a stand-alone personal computer version that runs on DOS based machines. It has a generic focus (not tailored to any one industry or firm) and should be able to assist with an information presentation task for a target user. It does not include any industry specific forms.

Development Framework/Environment

The INFORMEX development environment needed the ability to represent the presentation formats and content information along with the knowledge that would guide the recommendations. The representation task was well suited to an object-oriented environment [Cox86][StB86].

For example, INFORMEX needed to represent pie charts and bar charts as presentation formats in a knowledge base. Intuitively, pie charts are not well suited to presenting a large number of data, however, they are quite useful for presenting the proportional relationship between a smaller number of data. Alternatively, bar charts present an easy way to clearly identify high and low values, and they can logically accommodate more data. While the two presentation formats differ in these ways, they are also similar in a very important way. They both use area as their primary perceptual element and can be classified as an area-based type of graphical chart. Area-based charts share some common properties: They are not well suited to high precision representation (i.e., it is difficult to distinguish between the values of 2.45 and 2.47 on a pie or bar chart), and they are a good way to present summarized data. Through the use of inheritance, an object-oriented (o-o) approach can provide a rich representation environment. Continuing with the preceding example, PIE_CHART and BAR_CHARTS would represent independent objects. Each would be described by a set of attributes such as, complexity rating, maximum number of reasonable display data points, etc. The properties that are common for all area-based objects need not be defined for each object. Instead, a special kind of object called a class is created. A class stores all of the common property values for area-based objects. The PIE_CHART and BAR_CHART objects would be linked to the class AREA-BASED and would automatically inherit all of the common properties of area based presentation formats, unless the object property were assigned a local value unique to that object. To carry the example one step further, LINE-BASED and POINT-BASED are also classes of presentation formats that are linked to other presentation format objects. AREA-BASED, LINE-BASED, and POINT-BASED are all types of graphs and can inherit some of their properties from a higher level class named GRAPHICAL.

In addition to a rich knowledge representation environment, we want INFORMEX to be able to explain its conclusions. It should be able to cite the studies (or other sources used for the development of the knowledge base), experimental environment of the studies, and findings if the INFORMEX user so inquires. The concept of Hypertext documents appears a viable vehicle to provide this information [Fid88]. Each study has been summarized in a text document that includes the citation, dependent measures, description of the experimental task and subjects, individual/cognitive measures, presentation formats that were evaluated, and the findings of the study. For an example of how this works, consider that during an INFORMEX session, INFORMEX recommends that the information be presented in a highly aggregated table format. If a user wants to know about what experiments produced this recommendation, INFORMEX would recall one of the summaries that show highly aggregated tables are well suited to low complexity tasks for either field dependent or field independent types of individuals. By focusing on the word aggregation in the findings section, the user would be chained to all studies that examined level of aggregation. Alternatively, the user could explore why tables were recommended by selecting the word table and linking to the next study about tables.

Development Products

Several expert system shells were evaluated for the INFORMEX prototype. Many of these did not support the object-oriented framework and did not present a suitable representation alternative. Mahogany Professional by Emerald Intelligence was chosen because it supports the o-o environment and provides a rich rule structure.

The Mahogany rule structure is based on an

IF *some set of conditions is True*

THEN *a hypothesis is confirmed or assignments are made*

The IF portion of the rule supports deep conditions and pattern matching. For example, if the user has indicated that presentation precision is important, an IF statement might check for all objects (presentation formats) that have a high precision accuracy. Rather than checking the accuracy property of each object separately, the statement

IF *<graphical.precision> is greater than or equal to 4*

would identify all graphical types of objects with the ability to display data in a highly precise manner. The THEN portion of the rule structure is also very powerful. It allows for the creation of new objects, object property assignments, and the fulfillment of inference goals. Figure 3 contains sample INFORMEX rules.

```
RULE #2 priority 30 - CrS27
 IF ------------------------------
     (1)      the task action is comparison [threshold 0.20]
     (2) and the task complexity is "1 variable" [threshold 0.20]
     (3) and the task structure is structured [threshold 0.20]
 THEN ----------------------------
     (1)      grouped bar chart recommend is yes [certainty 1.00]
     (2) and simple bar chart recommend is yes [certainty 1.00]
     (3) and three d chart recommend is no [certainty 1.00]

RULE #3 priority 30 - Was32
 IF ------------------------------
     (1)      the task type is intellective [threshold 0.21]
     (2) and the task action is comparison [threshold 0.20]
     (3) and the task complexity is "2 variables" [threshold 0.20]
     (4) or  the task complexity is "more than 2 variables" [threshold
0.20]
     (5) and the task structure is structured [threshold 0.21]
 THEN ----------------------------
     (1)      grouped bar chart recommend is yes [certainty 0.60]
     (2) and simple bar chart recommend is yes [certainty 0.60]

RULE #8 priority 50 - find candidate presentation format objects
 IF ------------------------------
     (1)      the report format recommend is yes [threshold 0.20]
 THEN ----------------------------
     (1)      presentation format recommendations is
objectname(<report format>) [certainty 1.00]
     (2) and presentation format  is done [certainty 1.00]
```

Figure 3. Sample INFORMEX Rules

Several professional hypertext systems were also evaluated. INFORMEX needed a text retrieval system that could automatically link the similar terminology between the studies. We have selected Minds from Terra Inc. to drive the text retrieval system. It is used to link all of the studies based on similar performance measures, task environments, individual characteristics, presentation formats, or findings. Any key work can be quickly located in all relevant studies.

Statistics of the Knowledge Base

The INFORMEX knowledge base consists of 73 rules. Most of these rules have three to six conditions that lead to inferences about presentation format and content. The possible format and content recommendations are represented in 34 objects with the inheritance characteristics described in the previous section. The findings of some studies were very explicit and allowed the rules to make a specific recommendation, i.e. vertically grouped bar charts as a change from a base case. Many studies, however, only lead to a general inference such as area-based format with summary data. This weaker inference suggests that any area-based format (pie, bar, stacked bar) is an eligible recommendation candidate.

Since different studies sometimes produced conflicting results, the rule's certainty factors provide additional insight about the strength of the recommendation. For example, a given set of conditions (intellective task requiring comparison and recall for high analytics) might recommend with .85 certainty that area-based formats are appropriate, while at the same time recommending with a .65 certainty that tables should be used.

Sample Sessions

This section will describe two sample sessions for INFORMEX. The first session, Figure 4, will follow the approach of a well prepared consultation where most of the answers to INFORMEX's questions are available. This session will pursue a recommendation for a well defined intellective task for a middle manager:

Question	Response
What is the task type?	intellective
What is the task action?	comparison, re-trieval
What is the task complexity?	2 variables
User's cognitive complexity?	field dependent
User's functional knowledge?	medium
Which presentation formats is the user most familiar with?	tabular
User's cognitive type?	unknown
What is the task structure?	structured
What is the ask environmental complexity?	medium

The conclusions from this session follow:

```
* * * * * * *   C O N C L U S I O N S   * * * * * * * *

the information user information request
   is low  [certainty 1.00]

the presentation format recommendations
   is table  [certainty 0.64]
   is scatter plot chart  [certainty 0.71]
   is three d chart  [certainty 0.70]
   is segmented bar chart  [certainty 0.80]
   is line chart  [certainty 0.79]
   is area chart  [certainty 0.80]
   is simple bar chart  [certainty 1.00]
   is grouped bar chart  [certainty 0.70]
   is star chart  [certainty 0.70]
   is pie chart  [certainty 0.70]
   is column chart  [certainty 0.70]

the presentation content recommendations
   is change from base case  [certainty 1.00]
   is raw data  [certainty 0.99]
   is statistical transformation  [certainty 0.80]

* * * * * * *   C O N C L U S I O N S   * * * * * * * *
```

Figure 4. Sample Session 1

Question	Response
What is the task type?	planning
What is the task action?	trend identification and
find relationships	
What is the task complexity?	more than 2 vari- ables
What is the task structure?	user-defined
User's cognitive style?	unknown
User's functional knowledge	high
User's cognitive complexity	unknown
Which presentation format is the user most familiar with?	unknown
User's cognitive type	unknown
What is the ask environmental complexity?	high

```
The conclusions from session #2 follow:

* * * * * * *   C O N C L U S I O N S   * * * * * * * *

the information user information request
     (no values)

the presentation format recommendations
   is table  [certainty 0.50]
   is scatter plot chart  [certainty 0.89]
   is three d chart  [certainty 0.99]
   is segmented bar chart  [certainty 0.99]
   is line chart  [certainty 0.99]
   is area chart  [certainty 0.99]
   is simple bar chart  [certainty 0.87]
   is grouped bar chart  [certainty 0.89]
   is star chart  [certainty 0.89]
   is pie chart  [certainty 0.89]
   is column chart  [certainty 0.89]

the presentation content recommendations
   is change from base case  [certainty 1.00]
   is raw data  [certainty 0.85]
   is statistical transformation  [certainty 0.83]

* * * * * * *   C O N C L U S I O N S   * * * * * * * *
```

Figure 5. Sample Session 2

The second sample session, Figure 5, will inquire about a planning task with little knowledge about the individual factors of the user:

Interpretation of Sample Sessions

Though there is some support for several presentation formats and content recommendations, the higher certainty factors point to simple bar charts presented as a change from a base case for session one. INFORMEX also suggests that this information user will not want a large volume of information. This is indicated by 'information user information request is low' finding. Though raw data as the mode of presentation content also has almost equal support to change from a base case (.99 versus 1.00), the information request is low suggests that some level of summarization is recommended.

Session 2 conclusions are less exact than session 1. While tables are clearly not appropriate (certainty = .50), four formats received a certainty rating of .99 and five other formats have a .89 rating. A more careful examination reveals that the four highest ranking formats use a line as their primary perceptual element. The presentation content recommendation was again change from a base case. No conclusion was available for the information request volume.

CHAPTER V

SUMMARY AND CONCLUSIONS

Developing INFORMEX's knowledge base from a broad group of research findings has proven to be a difficult task. The inconsistencies in terminology and results of the studies complicated the knowledge building process. Yet, even given these obstacles, INFORMEX has demonstrated that rule based expert systems can be used as the knowledge vehicle for research findings. The development of the rule worksheet was a key factor in successfully extracting meaningful rules from the studies.

Though INFORMEX's recommendations are sometimes less conclusive than a user might like, i.e., a recommendation of both tables and graphs with close certainty weights, this is a true reflection of the state of research in this field for some task and individual factor combinations. This project has demonstrated the ability of knowledge based systems to integrate the results from several studies in a research area.

Classifying the existing research in the presentation question field by task, individual factors, presentation format and content, and dependent measures has been a second benefit of this project. This classification and review of the literature has identified areas where little or no research has been performed.

CHAPTER VI

FUTURE DIRECTIONS FOR INFORMEX

We plan to begin field testing this expert system at a company that has already expressed an interest in the project. The nature of expert systems requires that the knowledge base for INFORMEX will continue to be refined and grow as new knowledge about information presentation becomes available. And considering that the presentation question is a fertile research area, new and more methodologically precise studies will continue to refine our understanding of this area.

Ideally, future versions of INFORMEX will be an embedded part of a company's MIS. User cognitive profiles could be retained in a database as well as task classifications for various recurring types of managerial activities. A systems analyst would consult INFORMEX and simply identify the target user and type of activity that the information will be used for. Since the answers to many of INFORMEX's questions would be available in a database, system consultation time could be greatly reduced. In a truly integrated environment, an end-user could request information by variable name and INFORMEX could direct a report writer to create the report. INFORMEX is a first step in that direction.

References

[Ack67] Ackoff, Russell L., "Management Misinformation Systems," *Management Science*, Volume 14, Number 5, (May 1967), p. B147-156.

[BaL77] Bariff, M.L. and Lusk, E.J., "Cognitive and Personality Tests for the Design of Management Information Systems," *Management Science*, Volume 23, Number 8, (April 1977), pp. 820-829.

[BaO89] Barker, Virginia E. and O'Connor, Dennis E., "Expert Systems for Configuration at Digital: XCON and Beyond," *Communications of the ACM*, Volume 32, Number 3, (March 1989), pp. 298-317.

[BeD79] Benbasat, Izak and Dexter, Albert S., "Value and Events Approaches to Accounting: An Experimental Evaluation," *The Accounting Review*, Volume 54, (October 1979), pp. 735-749.

[BeD85] Benbasat, Izak and Dexter, Albert S., "An Experimental Evaluation of Graphcial and Color-Enhanced Information Presentation," *Management Science*, Volume 31, Number 11, (November 1985), pp. 1348-1364.

[Ber83] Bertin, *The Semiology of Graphics*, Madison: University of Wisconsin Press.

[BeS77] Benbasat, Izak and Schroeder, Roger, G., "An Experimental Investigation of Some MIS Design Variables," *MIS Quarterly*, (March 1977), pp. 37-48.

[ChD74] Chervany, Norman L., and Dickson, Gary W., "An Experimental Evaluation of Information Overload in a Production Environment," *Management Science*, 20, June, 1974, 1335-1344.

[Cox86] Cox, Brad J., *Object-Oriented Programming: An Evolutionary Approach*, Addison-Wesley Publishing Company, Reading, MA, (1986).

[CrS32] Croxton, Frederick E. and Stein, Harold, "Graphic Comparisons by Bars, Squares, Circles, and Cubes," *Journal of the American Statistical Association*, Volume 27, (1932), pp. 54-60.

[DDM86] Dickson, Gary W., DeSanctis, Gerardine, McBride, D.J., "Understanding the Effectiveness of Computer Graphics for Decision Support: A Cumulative

Experimental Approach," *Communications of the ACM*, 29, (January 1986), 40-46.

[DSC77] Dickson, Gary W., Senn, James A., and Chervany, Norman L., "Research in Management Information Systems: The Minnesota Experiments," *Management Science*, Volume 23, Number 9, (May 1977), 913-923.

[Dav81] Davis, Donald, "An Experimental Investigation of the Form of Information Presentation, Psychological Type of the User, and Performance within the Context of a Management Information System," Dissertation, University of Florida, (1981).

[Dav85] Davis, Larry R., "The Effects of Question Complexity and Form of Presentation on the Extraction of Question-Answers from an Information Presentation," Ph.D. Dissertation, Indiana University, (1985).

[DeG87] DeSanctis, Gerardine and Gallupe, Brent, "A Foundation for the Study of Group Decision Support Systems," *Management Science*, Volume 33, Number 5, (May 1987), pp. 589-609.

[Des84] DeSanctis, Geradine, "Computer Graphics as Decision Aids: Directions for Research," *Decision Sciences*, Volume 15, (1984), pp. 463-487.

[DoB88] Dos Santos, Brian L., Bariff, Martin L., "A Study of User Interface Aids for Model-Oriented Decision Support Systems," *Management Science*, 34, April, 1988.

[Edo87] Edosomwan, Johnson Almie, "Ten Design Rules for Knowledge Based Expert Systems," *IE*, (August 1987), pp 78-80.

[Fid88] Fiderio, Janet, "A Grand Vision," *Byte*, (October 1988), pp. 237-243.

[GeS82] Geiselman, Ralph E. and Samet, Michael G., "Personalized Versus Fixed Formats for Computer-Displayed Intelligence Messages," *IEEE Transactions on Systems, Man, and Cybernetics*, SMC-12, July/August, 1982, 490-495.

[GGH86] Gosler, Martin, D., Green, Gary I., and Hughes, Terry H., "Decision Support Systems: An Empirical Assesement for Decision Making," *Decision Sciences*, 17, 1986.

[Gha81] Ghani, Jawaid Abdul, "The Effects of Information Representation and Modification on Decision Performance," Dissertation, University of Pennsylvania, (1981).

[GLR89] Gillan, Douglas J., Lewis, Robert, and Rudisill, Marianne, "Models of User Interactions with Graphical Interfaces: I. Statistical Graphs," *Proceedings of CHI*, Austin Texas, (May 1989), pp. 375-380.

[Hub83] Huber, George P., "Cognitive Style as a Basis for MIS and DSS Designs: Much Ado About Nothing?" *Management Science*, Volume 29, Number 5, (May 1983), pp. 567-579.

[JDD85] Jarvenpaa, Sirkka L., Dickson, Gary W., and DeSanctis, Gerardine, "Methodological Issues in Experimental IS Research: Experiences and Recommendations," *MIS Quarterly*, (June 1985), pp. 141-156.

[Jar89] Jarvenpaa, Sirkka L., "The Effect of Task Demands and Graphical Format on Information Processing Strategies," *Management Science*, Volume 35, Number 3, (March 1989), pp. 285-303.

[Lau87] Lauer, Thomas W., "The Effects of Variations in Information Complexity and Form of Presentation on Performance for an Information Extraction Task," Ph.D. Dissertation, Indiana University, 1987.

[LMM86] Luconi, Fred, Malone, Tohmas W., and Scott Morton, Michael S., "Expert Systems: The Next Challenge for Managers," *Sloan Management Review*, (Summer 1986), pp. 3-13.

[Luc81] Lucas, Henry C., "An Experimental Investigation of the Use of Computer-Based Graphics in Decision Making," *Management Science*, Volume 27, Number 7, (July 1981), pp. 757-768.

[LuK79] Lusk, Edward, J. and Kersnick, Michael, "The Effect of Cognitive Style and Report Format on Task Performance: The MIS Design Consequences," *Management Science*, Volume 25, Number 8, (August 1979), pp. 787-798.

[LuN80] Lucas, Henry, C. and Nielsen, Norman, R., "The Impact of the Mode of Information Presentation on Learning and Performance," *Management Science*, Volume 26, Number 10, (October 1980), pp. 982-992.

[OtD82] Otley, David T. and Dias, Francisco J.B., "Accounting Aggregation and Decsion-Making Performance: An Experimental Investigation," *Journal of Accounting Research*, Volume 20, Number 1, (Spring 1982), pp. 171-188.

[Pay82] Payne, John W., "Contingent Decision Behavior," *Psychological Bulletin*, Volume 92, Number 2, 1982, pp. 382-402.

[Rau88] Rauch-Hinden, Wendy B., *A Guide to Commercial Artificial Intelligence*, Prentice-Hall, New Jersey, 1988.

[Reu84] Remus, William, "An Empirical Investigation of the Impact of Graphical and Tabular Data Presentations on Decision Making," *Management Science*, 30, May, 1984, 533-541.

[Reu87] Remus, William, "A Study of Graphical and Tabular Displays and Their Interaction with Environmental Complexity," *Management Science*, 33, (September 1987), 1200-1204.

[REB89] Rangaswamy, Arvind, Eliashberg, Jehoshua, Burke, Raymond R., and Wind, Jerry, "Developing Marketing Expert Systems: An application to International Negotiations," *Journal of Marketing*, Volume 53, (October 1989), 24-39.

[Rob83] Robey, Daniel, "Cognitive Style and DSS Design: A Comment on Huber's Paper," *Management Science*, Volume 29, Number 5, (May 1983).

[Sam87] Samson, Dolly, "Object-Oriented Requirements Definition: Closing the Disconnect," *Proceedings of the 1987 IEEEE International Conference on Systems, Man, and Cybernetics*, (October, 1987), 217-221.

[SaT88] Sayles, William and Thomas, Jack, "Finding and Fixing Network Faults with an Expert System," *Data Communications*, (June 1988), pp. 149-165.

[StB86] Stefik, Mark and Brobow, Daniel, "Object Oriented Programming: Themes and Variations," *AI Magazine*, Volume 6, Number 4, (Winter 1986), 40-62.

[UmS88] Umanath, Narayan S., Scamell, Richard W., "An Experimental Evaluation of the Impact of Data Display Format on Recall Performance," *Communications of the ACM*, 31, May, 1988.

[Vas77] Vasarhelyi, Miklos Antal, "Man-Machine Planning Systems: A Cognitive Style Examination of Interactive Decision Making," *Journal of Accounting Research*, Spring, 1977, pp. 138-153.

[WaD83] Watson, Collin J. and Driver, Russell W., "The Influence of Computer Graphics on the Recall of Information, "MIS Quarterly, 7, March, 1983, 45-53.

[Was27] Washburne, John Noble, "An Experimental Study of Various Graphic, Tabular, and Textual Methods of Presenting Quantitative Material," *Journal of Educational Psychology*, Volume 18, Number 6, September, 1927, pp. 361-376.

[ZBM83] Zmud, R., Blocher, E., and Moffie, P., "The Impact of Color Graphic Report Formats on Decison Performance and Learning," *Proceedings of the Fourth International Conference on Information Systems*, (1983), pp. 179-193.

[Zmu78] Zmud, Robert, W., "An Empirical Investigation of the Dimensionality of the Concept of Information," *Decsion Sciences*, Volume 9, Number 2, April, 1978, pp. 187-195.

APPENDIXES

APPENDIX A
SUMMARIES OF EMPIRICAL STUDIES

Bal77
Bariff, M.L., and Lusk, E.J., "Cognitive and Personality Tests for the Design of Management Information Systems," Management Science, 23, April, 1977, 820-829.

MEASURES: readability, completeness, ability to locate abstract data, amount of detail

TASK: Seventeen supervisors and administrators from a community nursing service evaluated three report sets for readability, completeness of data, simple retrieval and abstraction of data, and volume of detail

INDIVIDUAL: Psychological type, organizational level

PRESENTATION: Raw data v. statistical transformation and tabular v. graphic

FINDINGS:
* Psychological profiles were uniquely identified with an organizational level
* Both high and low analytic preferred the disaggregated reports with raw data

BeD79 Benbasat, Izak and Dexter, Albert S., "Value and Events Approaches to Accounting: An Experimental Evaluation," The Accounting Review, 54, October, 1979, 735-749.

The field independence (cognitive complexity) type is equated with the high analytic (psychological) type.

MEASURES: profit, decision time, number of reports requested

TASK: A combination of 48 accounting students, faculty, and professional accountants acted as inventory/production managers through a computer simulation. The subjects had to select an order quantity, reorder point, and production figures in 15 simulated periods.

INDIVIDUAL: The subjects were controlled for psychological type.

PRESENTATION: Both groups received tabular output via a CRT terminal. One group received information by making database inquiries and specifying which variables to be include. The other group received structured/aggregate reports with a fixed format.

FINDINGS:

* There were no profit performance differences between presentation types.
* Subjects using the database inquiry method took longer to make decisions
* Structured/aggregate ("value") reports are better suited for high analytics
* Database inquiry ("events") is better suited for low analytics
* Low analytic subjects with structured/aggregate reports had the poorest performance, and are shown to perform better with disaggregated reports.
* High analytics who used the database inquiry systems requested 50% more historical information than the low analytics.
* Low analytics who used the aggregate/structured reports requested 50% more reports than the high analytics
* Low analytics prefer and perform better with disaggregate reports

BeD85
Benbasat, Izak, & Dexter, Albert S., "An Experimental Evaluation of graphical and Color-Enhanced Information Presentation," Management Science, 31, November, 1985.

A mismatch between information presentation and personality type can cause field dependent subjects to perform poorly.

MEASURES: profit, decision time, report attribute ratings

TASK: Thirty-five graduate and undergraduate marketing students completed a marketing problem (the territory allocation problem) and had to allocate a promotional budget to three territories.

INDIVIDUAL: The subjects were controlled for cognitive complexity (field in/dependence).

PRESENTATION: The information was presented in mono- and multi-color tabular and line graph formats.

FINDINGS:
* No profit differences between tabular and graphical groups
* Subjects using multi-color performed better than those using mono-color reports
* The Multi-color graphical group exhibited the most learning over the mono-color graphical group
* Field-dependent subjects with mono-color reports performed the worst and showed no profit improvement (the only group w/o improvement) during the last five periods
* Field-dependents with color reports performed 73% better than field-independents with mono-color reports
* Subjects with mono-color graphical reports had the highest time figures, though not statistically significant
* Tabular reports were perceived to be more accurate and to have a better format
* Graphical reports were perceived to be more relevant and useful for formulating decisions
* Multi-color reports were thought to more clearly identify when good decisions were being made. Highest understandability was given by field-dependents to tabular reports and the lowest was given by field-dependents to graphical reports

BeS77
Benbasat, Izak and Schroeder, Roger G., "An Experimental Investigation of Some MIS Design Variables," MIS Quarterly, March, 1977, 37-48.

MEASURES: performance (cost), decision making time, number of reports requested

TASK: Thirty-two production operations management students interacted with a computer simulation of a production environment. The subjects had to set an order point, order quantity, and daily production figures for twenty periods.

PRESENTATION: Some of the subjects received tabular reports, while others received graphical reports. The number of reports available were divided into two categories of "necessary" (11 reports) and "overload" (19 reports). Exception reporting was also made available to one group. All reports were presented via CRT terminal displays.

INDIVIDUAL: The subjects were controlled for psychological type and high/low functional knowledge.

FINDINGS:
* The graphical group had 6% lower costs than the tabular group
* Both the graphical and high functional knowledge groups used fewer reports
* Subjects with the overload set of reports requested more reports than the subjects with the necessary set of reports
* Low analytic subjects who had low functional area knowledge requested the largest number of reports
* Subjects with the graphical reports requested fewer reports from the overload report set than subjects with listed tabular reports
* Subjects with high functional knowledge requested fewer reports from the overload report set than subjects with a low functional area knowledge

OTHER FINDINGS (not statistically significant):
* Exception reporting did not improve time or cost performance, nor reduce the number of reports requested
* Decision making style or functional knowledge did not affect cost or time performance

ChD74
Chervany, Norman L., and Dickson, Gary W., "An Experimental Evaluation of Information Overload in a Production Environment," Management Science, 20, June, 1974, 1335-1344.

A reduction in information overload via the use of descriptive statistics can both improve performance and make performance more predictable.

MEASURES: decision time, performance (cost), confidence

TASK: Twenty-two graduate business students sought to minimize production cost by choosing production schedules, labor force size, and raw material ordering in a computer simulated production environment over a ten period problem.

PRESENTATION: Tabular formats of either raw data or statistically summarized data.

FINDINGS:
* The group using the statistically summarized reports yielded 4.6% lower total costs than the raw data group
* The statistically summarized group took approximately 25% longer per decision and expressed slightly less confidence in their decision
* The cost variance within the raw data group was approximately twice that of the statistically summarized group
* The confidence variance within the statistically summarized group was much higher than the raw data group
* The statistically summarized group appeared to identify and focus on the key factor of the case (stockout costs), yet they did not seem to realize they had found the key factor

CHS88
Callahan, J., Hopkins, D., and Shneiderman, B., "An Empirical Comparison of Pie vd. Linear Menus," Human Factors in Computing Systems: CHI 1988 Conference Proceedings, May 15-19, 1988, Washington D.C., 95-100.

MEASURES: seek time, accuracy

TASK: Thirty-three undergraduate students with little or no mouse experience.

INDIVIDUAL:

PRESENTATION: Linear menus v. pie menus of up to 8 items and linear, pie, and unclassified menu item organizations

FINDINGS:
* Pie tasks and linear tasks did not significantly differ in performance
* Pilot study found pie menus to be 15% faster than linear menus
* Pie or linear organization of menu items was better than unclassified

Col89
Cole, William G., "Understanding Bayesian Reasoning," CHI '89 Proceedings, May, 1989, 381-386.

MEASURES: accuracy of understanding, flexibility of understanding

TASK: Ninety psychology undergraduate students estimated the probability that a patient really had a disease as described in the classic Casscells, Scholenberger, and Grayboys problem. The students were then given additional training in Bayesian reasoning and presentation format interpretation then retested with immediate feedback. A final Bayesian problem, different from the first 16, stated a given prevalence and asked the subjects to rate the relative importance of two factors (test specificity and sensitivity).

INDIVIDUAL:

PRESENTATION: tabular, signal detection curve (line chart), detection bar (x-y chart), probability map (Venn diagram)

FINDINGS:
* Subjects demonstrated substantial learning after additional training in Bayesian reasoning
* Raising both specificity and sensitivity has significantly more impact than raising one independently
* Any of the four representations improved performance beyond improvements from simple practice

CrS32
Croxton, Fredrick E. and Stein, Harold, "Graphic Comparisons by Bars, Squares, Circles, and Cubes," Journal of the American Statistical Association, 1932.

MEASURES: accuracy

TASK: Five hundred and fifty students compared two figures of like shape, but differing in size, and were asked to estimate the size of the smaller figure in relation to the larger one.

PRESENTATION: Forty different shapes were used consisting of various representations of horizontal bars, squares, circles, and cubes.

FINDINGS:
* Estimates based upon bars were more accurate than estimates based upon squares, circles, or especially cubes
* Estimates based upon squares were clearly more accurate than estimates based upon cubes
* Whether the shapes are drawn at baseline or vertically centered made no difference.

Dav81
Davis, Donald, "An Experimental Investigation of the Form of Information Presentation, Psychological Type of the User, and Performance within the Context of a Management Information System" Dissertation, University of Florida, 1981.

MEASURES: decision cost, decision time, subject confidence in decision

TASK: Ninety-six MBA students were evaluated in a computer simulated production environment.

INDIVIDUAL: The subjects were controlled for cognitive type.

PRESENTATION: Two presentation formats (tabular v. bar chart) and two levels of summarization (raw data v. statistically summarized) were examined.

RESULTS:
* In the absence of cognitive type knowledge, a firm should use tabular-raw data or graphical-raw data for a production environment
* Sensing-Thinking types had the best cost performance with graphical raw data
* A combination of cost performance and decision time suggests that Sensing-Feeling production managers can use either tabular-raw data or tabular-statistically summarized
* Intuitive-Feeling types had their best overall performance using tabular-raw data and graphical-statistically summarized
* Intuitive-Thinking types did not appear to be well suited to a production environment

Dav85
Davis, Larry R., "The Effects of Question Complexity and Form of Presentation of the Extraction of Question-Answers from an Information Presentation," Ph.D. Dissertation, Indiana University, 1985.

MEASURES: decision time, accuracy

TASK: Thirty MBA students answered five questions of varying complexity (5 levels) by viewing four presentation formats of complex time series accounting data. The data included one nominal, one ordinal, and one quantitative variable.

INDIVIDUAL:

PRESENTATION: tables, line graphs, bar charts, and pie charts

FINDINGS:
* For a simple retrieval task, tables required half the time of line and bar graphs, though performance accuracy was equal across formats
* When retrieval and comparison are part of the task, line and bar yield the highest accuracy and best decision time
* For tasks that require many comparisons and estimations, bar charts yielded the greatest accuracy, but the longest decision time
* For tasks that require many scans, identifications, estimates, and comparisons, pie charts and tables have the best performance and accuracy
* For an intensively comparison type of question, tables showed the highest accuracy and were equal in time performance to line graphs

DDM86
Dickson, Gary W., DeSanctis, Gerardine, McBride, D.J., "Understanding the Effectiveness of Computer Graphics for Decision Support: A Cumulative Experimental Approach," Communications of the ACM, 29, January, 1986.

MEASURES: interpretation accuracy, decision quality

TASK: The task complexity level was varied in three separate experiments by increasing the number of variables that had to be considered.

PRESENTATION: Balance sheet and income statement were shown with horizontal bar charts while ROA and ROI data were shown as double bars (grouped) in a vertical bar graph. Exact values were given at the end of each bar.

RESULTS:
* For the low complexity task, there were no significant performance (accuracy or quality) differences between graphical and tabular
* For the medium complexity task (2 variables), the graphical group outperformed the tabular group and perceived the task to be easier
* For the more complex task (multiple variables), the graphical group performed better with a large amount of material, while the tabular group did better with smaller chunks of information
* When accurate interpretation of values is important and when the user has experience with tabular presentations, tables are probably the better choice
* When the task activity involves seeing time dependent patterns in a large amount of data, graphs are a good presentation format
* Graphs may be the format of choice when presenting a large amount of data and desiring fairly specific recall shortly after the presentation

Der73
Dermer, Jerry, "Cognitive Characteristics and the Perceived Importance of Information," The Accounting Review, July, 1973, 511-519.

MEASURES:

TASK: Forty sales managers ranked the importance of seventy-two internally and externally generated financial, behavioral, and operational factors related to the performance of a sales manager's duties. The information was also classified as past, current, or future.

INDIVIDUAL: level of intolerance of ambiguity,

PRESENTATION:

HYPOTHESIS:
* Individuals intolerant of ambiguity will tend to perceive more information to be important than those tolerant of ambiguity {SUPPORTED}
* Individuals intolerant of ambiguity will tend to judge as important information that is well defined, familiar, and certain {SOME}

FINDINGS:
* Information which is well defined and highly certain (e.g. current financial) is strongly correlated with the intolerance of ambiguity measure
* The importance of external, behavioral data was differentiated by the time factor with only current behavioral data being positively correlated to the intolerance of ambiguity measure
* Ambiguity tolerance and the amount of information perceived to be important were negatively correlated
* Conceptually concrete individuals prefer more information than do more abstract individuals

DoB88
Dos Santos, Brian L., Bariff, Martin L., "A Study of User Interface Aids for Model-Oriented Decision Support Systems," Management Science, 34, April, 1988.

MEASURES: problem identification, problem prioritization

TASK: Forty-six undergraduate business students evaluated a business case with three controllable variables. The subjects interacted with a DSS to enhance their understanding of the case.

PRESENTATION: All output was presented via CRT displays. One group received reports that were variable based (subjects could designate which variables to include) while the other group received exception reports (automatically chose variables that deviated from user-defined criteria. The reports were further divided into actual values versus differences computed from a base case.

FINDINGS:
* The groups receiving difference from a base case reports performed significantly better than the groups receiving actual variable values
* Exception based reports negatively affected problem finding
* System guided group performed better than user guided group

GeS82
Geiselman, Ralph E. and Samet, Michael G., "Personalized Versus Fixed Formats for Computer-Displayed Intelligence Messages," IEEE Transactions on Systems, Man, and Cybernetics, SMC-12, July/August, 1982, 490-495.

MEASURES: objective test scores, average number of notes written, test score divided by number of notes

TASK: Thirteen U.S. Army officers viewed 24 intelligence messages for 20 seconds each.

PRESENTATION: One group received messages in a predetermined, fixed format while the other group was allowed to customize the format to their own specifications. Both formats contained only tabular information.

FINDINGS:
* The personalized-format group did not show higher overall objective test scores than the fixed-format group
* The fixed-format group wrote down significantly more messages than the personalized group
* When the objective test scores were adjusted for the number of messages recorded, the personalized-format group scored significantly higher. This implies that the personalized -format group learned more from viewing the messages rather than the notes

GGH86
Gosler, Martin D., Green, Gary I., & Hughes, Terry H., "Decision Support Systems: An Empirical Assessment for Decision Making," Decision Sciences, 17, 1986.

Availability of relevant information typically improves the accuracy of decisions, but irrelevant and excess information which is presented to a decision maker may make the identification of relevant information more difficult. Individuals under time pressure tend to accentuate negative evidence and to use fewer information attributes.

MEASURES: number of alternatives considered, decision time, decision confidence, amount of data considered, decision strategy, performance

TASK: Forty-three professional sales and marketing personnel examined an ill-structured marketing problem.

PRESENTATION: Three data levels representing insufficient, sufficient, and overload volumes of data were evaluated. Reports were primarily tabular, however some graphical output could be requested through the DSS.

FINDINGS:
* Data level did not significantly affect decision maker confidence, decision making time, or decision making processes
* Subjects exposed to a low data level indicated a greater understanding of the alternatives and the impact of the alternatives

Gha81
Ghani, Jawaid A., "The Effects of Information Representation and Modification on Decision Performance," Dissertation, University of Pennsylvania, 1981.

MEASURES: profits, decision time, user preferences

TASK: Fifty-three MBA students made a series of inventory ordering decisions (overtime v. penalty costs) based on a simulated marketing environment.

INDIVIDUAL: Cognitive Type

PRESENTATION: Both tabular and graphical were used with a slight change midway through the experiment in the amount of information presented.

FINDINGS:
* Users are likely to oppose a change in information representation and will likely indicate a strong preference for their current information representation, even after having used an alternative representation
* After a change, either in information content or in information representation, an initial deterioration in performance can be expected
* Graphics lead to poorer quality decisions and longer decision times
* Cognitive Type was not an important differentiating factor
* Some indications that "feeling" types will perform better with and prefer graphical representations
* Some indications that "sensing" types will perform better with and prefer tabular representations
* Tasks that require simple retrieval should use tabular representation
* Tasks that require perception of relationships among data should use graphical representation

GLR89
Gillan, Douglas J., Lewis, Robert, and Rudisill, Marianne, "Models of User Interactions with Graphical Interfaces: I. Statistical Graphs," in the proceedings of CHI, 1989, ACM, New York, 1989, pp. 375-380.

MEASURES: speed, accuracy, perceptual complexity, figure-to-axes, informational complexity

TASK: Thirty-one engineers and scientists performed four trials on each presentation type. Two of the trials were retrieval tasks and two were comparison tasks.

PRESENTATION: Seventeen types of graphs were evaluated. They were categorized by their basic perceptual element into point, line, or area types. Line, ray, surface, stick figure, segmented bar, and 3-D graphs are examples of line types while bar, checked bar, checked bar with lines, column, filled line, textured surface, pie, and star graphs are classified as area types.

FINDINGS:
* The subjects responded faster and more accurately to comparison rather than identification tasks
* Comparative judgements were made from the graphs without first identifying the values of the comparison variables
* Informational complexity had a strong effect on performance with the retrieval task
* Primary perceptual element and data-ink ratio have a greater effect with the comparison task
* Area graph types produced the fastest and most accurate performance

Jar89J
Jarvenpaa, Sirkka L., "The Effect of Task Demands and Graphical Format on Information Processing Strategies," Management Science, 35, March, 1989.

Information presentation format influences the decision time and the selection of acquisition and evaluation strategies by influencing the cognitive costs and benefits of the task environment. Other factors influencing the decision time and the choice of strategies include the characteristics of the task and the interactions between the presentation format and the other task demands. The interactions between the task demands and the graphical format appear to be complex and may impact different stages of decision process differently (e.g., acquisition versus evaluation).

TASK: Sixty MBA students evaluated a case using four different structured decision strategies. They had to choose a site for a restaurant from six locations with seven attributes

PRESENTATION: Displays can be organized by alternatives, attributes or a matrix of alternatives and attributes. Alternatives and attributes were represented by horizontal bar charts while the matrix was presented as a grouped bar chart.

RESULTS:
* Acquisition direction was found to be a function of the graphical format, not a function of the congruence between the graphical format and task
* Evaluation direction was found to be influenced by the congruence between the demands of the task and the graphical format
* Decision makers adapt to incongruent situations (task demands and presentation format suggest conflicting strategies) by varying decision time rather than accuracy
* The way that graphical information is arranged on a display affects the order in which decision makers acquire information
* Grouped bar charts tended to elicit attribute processing

JDD85
Jarvenpaa, Dickson, & DeSanctis, "Methodological Issues in Experimental IS Research: Experiences and Recommendations," MIS Quarterly, June, 1985.

MEASURES: profit performance, decision time, report attribute ratings

TASK: Sixty-three graduate students evaluated a marketing case with three levels of task complexity (controlled by the number of distractors).

PRESENTATION: simple and grouped bar charts

RESULTS:
* Subjects using grouped bar charts in the low complexity task will perform better in a problem solving task than subjects using simple bar charts

Lau87
Lauer, Thomas W., "The Effects of Variations in Information Complexity and Form of Presentation on Performance for an Information Extraction Task," Ph.D. Dissertation, Indiana University, 1987.

MEASURES: accuracy, time

TASK: The experiment focused on the information extraction task and was performed by 30 MBA students.

PRESENTATION: Line Graph, Bar Chart, Grouped Bar Chart, Pie Chart, Table

FINDINGS:
* As the Form of Presentation and Information Complexity vary, performance will also vary
* Subjects using tables used less time than subjects using any of the graphical forms. The lower complexity information also required less time
* Overall, subjects were least accurate with a line graph and most accurate with a table
* Pie charts were relatively insensitive to increases in information complexity
* Bar charts and line charts yielded the best performance when identifying highest or lowest values
* Tables were the most effective when estimating differences

Luc81
Lucas, Henry C., "An Experimental Investigation of the Use of Computer-Based Graphics in Decision Making," Management Science, 27, July, 1981, 757-768.

...including the option for both tabular and graphics data is a good policy.

MEASURES: cost performance

TASK: Executives participated in a computer simulation of a inventory control environment. The multi-period game required the executives to place annual orders based on forecasts and simulation information.

INDIVIDUAL: Each participant was tested for cognitive style using Barkin's instrument.

PRESENTATION: Information was presented in tabular hardcopy, tabular CRT, statistical line graph, combined tabular and graphical statistics, graphical simulation, and combined tabular and graphical simulation.

FINDINGS:
* Groups using the hardcopy reports performed significantly better than the group using the CRT without graphical output
* Graphics groups developed a better understanding of the problem
* Heuristic decision makers in the graphics group had the best simulation results
* Heuristics scored higher in the usefulness of frequency distributions and simulation output

* Results suggest that analytics may already have a model in mind; therefore, they simply use the reports to confirm or disprove their prior model
* Heuristics do not have a preconceived model and benefit more from a visual representation of the information

LuK79
Lusk, Edward J. and Kersnick, Michael, "The Effect of Cognitive Style and Report Format on Task Performance: The MIS Design Consequences," Management Science, 25, August, 1979, 787-798.

Individuals have developed strong conditioning bonds for presentation formats that they have used in the past; however, new conditioning bonds to other formats can be developed through training.

TASK: Four hundred and three undergraduate students were asked to retrieve and/or perform minor computations based on twenty questions over the information presented in the 5 report types. Twenty percent of the questions were simple retrieval while eighty percent required retrieval and minor computations.

INDIVIDUAL: The subjects were controlled for psychological type.

PRESENTATION: Five presentation formats were evaluated: raw data, tabular percentage transformation, histogram of raw data, cumulative frequency graphic of raw data, cumulative frequency graphic of the percentages.

FINDINGS:
* The tabular report group was perceived to represent a lesser degree of complexity than the graphical report group and resulted in performance optimization
* There is no statistically significant evidence that perceived complexity rankings can provide useful information regarding task performance differences
* High analytics out performed low analytics on all report types (stat. sig. for RD tabular, RD histogram, RD cumulative)

LuN80
Lucas and Nielson, "The Impact of the Mode of Information Presentation on Learning and Performance," Management Science, 26, October, 1980, 982-993.

Individual background differences do affect the way users respond to different presentation modes.

MEASURES: performance (profit), learning

TASK: Twelve MBA students, eighteen industrial engineers, and fourteen senior executives participated in a computer simulated logistics game. They were required to choose an amount of product to ship via several different competitors. The objective was to maximize profit by increasing sales and reducing logistics costs.

INDIVIDUAL: The subjects were measured for cognitive style, age, work/military experience.

PRESENTATION: The subjects evaluated four presentation formats in combinations of tabular v. graphical and hardcopy v. CRT.

FINDINGS:
* The hypothesis that additional information will result in greater learning and better performance was not strongly supported
* The CRT groups performed better than the hardcopy groups
* Graphical formats were not supported over tabular formats

OtD82
Otley, David T. and Dias, Francisco J.B., "Accounting Aggregation and Decision Making Performance: An Experimental Investigation," Journal of Accounting Research, 20, Spring, 1982, 171-188.

MEASURES: performance (% of error), decision time

TASK: Forty-eight undergraduate business students used a computer simulation model to make production decisions. Rather than optimizing production, the real task was to develop an understanding of the relationships between the decision variables and the outcomes of the model.

INDIVIDUAL: The participants were evaluated for cognitive complexity.

PRESENTATION: Four levels of aggregation represented in four tabular report sets. In particular, 3 of the sets aggregated the information by reducing the amount of data without changing the content (type I). The fourth set of reports aggregated by reducing both the amount and the content of the information (type II).

FINDINGS:
* Type I aggregation tends to improve performance, but type II aggregation was detrimental to performance
* Cognitive complexity was not significant
* Increasing aggregation caused performance to improve up to a point and then decline (inverted U shape)
* Performance varied by task complexity with the lower complexity type of task having better performance

Reu84
Remus, William, "An Empirical Investigation of the Impact of Graphical and Tabular Data Presentations on Decision Making," Management Science, 30, May, 1984, 533-541.

MEASURES: decision costs, individual regression modeled decision costs (for consistency), composite regression modeled decision costs

TASK: Fifty-three undergraduate candidates made production and workforce decisions for twenty-four periods. The first twelve periods were designated as the learning phase and the latter twelve as stable decision making.

INDIVIDUAL:

PRESENTATION: tabular, line graph

FINDINGS:
* During the learning and stable decision phases, there was no significant advantage for either type of display
* Based on the individual regression model, neither tabular nor graphical resulted in lower costs
* The regressed costs were significantly lower than the actual costs
* Based on the composite rules, the tabular display costs were significantly lower in both the learning and stable decision making phases
* Inconsistent decision making can offset the benefits of a presentation format

Reu87
Remus, William, "A Study of Graphical and Tabular Displays and Their Interaction with Environmental Complexity," Management Science, 33, September, 1987, 1200-1204.

MEASURES: decision costs, individual regression modeled decision costs (for consistency), composite regression modeled decision costs

TASK: Fifty-four MBA candidates (most employed) made production and workforce decisions. They were also controlled for environmental variability
INDIVIDUAL:

PRESENTATION: tabular, graphical

FINDINGS:
* During the learning and stable decision phases, there was no significant advantage for either type of display
* Based on the individual regression model, neither tabular nor graphical resulted in lower costs
* In low complexity environments, tabular displays yield lower costs
* In intermediate complexity environments, graphical displays had lower costs

UmS88
Umanath, Narayan S., Scamell, Richard W., "An Experimental Evaluation of the Impact of Data Display Format on Recall Performance," Communications of the ACM, 31, May, 1988.

MEASURES: recall of directional order, pattern recall, and specific fact recall, and pattern integration

TASK: Two hundred and forty-seven graduate and undergraduate students participated in two experiments that examined their specific recall abilities.

PRESENTATION: The information for the experiment was presented in tabular and bar chart form.

FINDINGS:
* The graphical format was superior for the recall of directional order and pattern.
* The graphical format was more effective for integrative pattern recall
* Simple specific fact recall was indifferent to format
* The researchers observed that the tabular group did more scribbling and made more notations on their reports than did the graphical group

Var77
Vasarhelyi, M., "Man-Machine Planning Systems: A Cognitive Style Examination of Interactive Decision Making," Journal of Accounting Research, Spring, 1977, 138-153.

MEASURES: Performance as evaluated by a panel of judges and attitudinal measures

TASK: Fifty students with some business experience made planning decisions using an interactive planning simulator (IPS) based on a balanced (equally qualitative and quantitative) business case

INDIVIDUAL: Cognitive Style, sex, computer experience, education

PRESENTATION: tabular

FINDINGS:
* Analytics and heuristics performed equally in a balanced planning situation
* Heuristics utilized less information than analytics
* Heuristics make decisions faster than analytics (partial support)
* Analytics liked utilizing computers more than heuristics
* Individual users will utilize less information than they expect

Not Statistically Significant, though directionally supported
* Analytics used the structured part of the IPS more than heuristics
* Heuristics will use the unstructured part of the IPS more than analytics
* Heuristics used more qualitative and less quantitative information than analytics

WaD83
Watson, Collin J. and Driver, Russell W., "The Influence of Computer Graphics on the Recall of Information," MIS Quarterly, 7, March, 1983, 45-53.

MEASURES: immediate and delayed recall

TASK: Twenty-nine junior and senior business students viewed representations of frequency data by geographic location. After a one minute exposure to the data, they had to rank order a cue list of the six highest frequency locations. Four weeks later the subjects completed the same ranking task without reviewing the data.

INDIVIDUAL:

PRESENTATION: Three dimensional graphical computer plots and tabular

FINDINGS:
* There were no significant differences in immediate or delayed recall between the three-dimensional graphical and tabular groups

Was27
Washburne, John N., "An Experimental Study of Various Graphic, Tabular, and Textual Methods of Presenting Quantitative Material," The Journal of Educational Psychology, 18, Sep., 1927.

MEASURES: accuracy

TASK: Three hundred primary and secondary aged students answered eighteen questions requiring retrieval/comparison of information from fifteen presentation formats.

PRESENTATION: The fifteen presentation formats included narrative, table, line, bar, and pictographs representations of the information.

FINDINGS:
* Presentation format significantly affects understanding
* Complexity (number of comparisons) does not determine format effectiveness
* Quantity of data and arrangement do significantly affect recall
* For complex, static comparisons (relative amounts), bar charts are recommended
* For simple, static comparisons, pictographs are recommended
* For dynamic comparisons (net change), linegraphs are recommended
* For specific value retrieval, statistical tables are recommended
* Pictographs were effective for very simple data, but very ineffective for complex data
* Logical arrangement is more important in respect to the recall of relative amounts
* Visual pattern in more important in respect to recalling specific amounts

ZBM83
Zmud, R., Blocher, E., Moffie, P. "The Impact of Color Graphic Report Formats on Decision Performance and Learning," Proceedings of the Fourth International Conference on Information Systems, 1983, pp. 179-193.

MEASURES: accuracy, learning

TASK: Fifty-one experienced cost accountants rated the risk of sample invoices in an internal auditing situation. The subjects performed a low complexity task (5 cues) for the first session and a high complexity task (9 cues) for a the second session. The subjects were instructed in how to rate the invoices. Thus, the experiment involved a relatively structured task in which subjects were provided with an appropriate decision model, but insufficient time to apply the model. Rather than having to "discover" a decision rule, subjects had to develop an effective strategy for applying the decision rule.

INDIVIDUAL: The subjects were controlled for cognitive complexity, age, functional experience, and quantitative abilities.

PRESENTATION: One group received back and white tabular reports while a second group evaluated color bar charts.

RESULTS:
* Color graphic report had the highest accuracy for low task complexity, but the lowest accuracy for high task complexity
* Report format and quantitative skill interacted significantly to affect accuracy; higher quantitative skills performed better with tables
* Report format and experience interacted significantly to affect decision confidence; more experienced subjects expressed more confidence with graphs
* Demographic attributes tend to be associated more strongly with confidence than accuracy
* Cognitive skills tend to be associated more with accuracy than confidence
* Report format differences were more influential than individual factors

Zmu78
Zmud, Robert W., "An Empirical Investigation of the Dimensionality of the Concept of Information," Decision Sciences, 9, April, 1978, 187-195.

MEASURES: identifying the dimensions of information, presentation format ratings by dimension TASK: preference survey PRESENTATION: table, bar chart, line graph
FINDINGS:
* Four classes of the dimensions of information were found:
 Quality of Information: relevant
 Relevancy Components: accurate, factual, quantity, timely
 Quality of Format: arrangement, readable
 Quality of Meaning: reasonable
* Graph(line) received the highest rating for the relevant, accurate, quantity, timely, readable, and reasonable dimensions
* Tabular and graphical had equal ratings in accuracy
* Bar chart received the worst rating in five of the eight categories

APPENDIX B
INFORMEX KNOWLEDGE BASE

```
* * *   R U L E S   * * *   of   C:\MAHOGANY\INFORMEX.30KB     * * *

RULE #1 priority 50 - flow control
 IF -----------------------------
    (1)      the presentation format  is done [threshold 0.20]
    (2) and the presentation content  is done [threshold 0.20]
 THEN ---------------------------
    (1)      evaluation  is complete [certainty 1.00]

RULE #2 priority 30 - CrS27
 IF -----------------------------
    (1)      the task action is comparison [threshold 0.20]
    (2) and the task complexity is "1 variable" [threshold 0.20]
    (3) and the task structure is structured [threshold 0.20]
 THEN ---------------------------
    (1)      grouped bar chart recommend is yes [certainty 1.00]
    (2) and simple bar chart recommend is yes [certainty 1.00]
    (3) and three d chart recommend is no [certainty 1.00]

RULE #3 priority 30 - Was32
 IF -----------------------------
    (1)      the task type is intellective [threshold 0.21]
    (2) and the task action is comparison [threshold 0.20]
    (3) and the task complexity is "2 variables" [threshold 0.20]
    (4) or  the task complexity is "more than 2 variables" [threshold
0.20]
    (5) and the task structure is structured [threshold 0.21]
 THEN ---------------------------
    (1)      grouped bar chart recommend is yes [certainty 0.60]
    (2) and simple bar chart recommend is yes [certainty 0.60]

RULE #4 priority 30 - Was32
 IF -----------------------------
    (1)      the task type is intellective [threshold 0.21]
    (2) and the task action is comparison [threshold 0.20]
    (3) and the task complexity is "1 variable" [threshold 0.20]
    (4) and the task structure is structured [threshold 0.21]
 THEN ---------------------------
    (1)      pictograph recommend is yes [certainty 0.60]

RULE #5 priority 30 - Was32
 IF -----------------------------
    (1)      the task type is intellective [threshold 0.21]
    (2) and the task action is "find relationships" [threshold 0.20]
    (3) and the task complexity is "1 variable" [threshold 0.21]
    (4) and the task structure is structured [threshold 0.21]
 THEN ---------------------------
    (1)      line-based recommend is yes [certainty 0.60]

RULE #6 priority 30 - Was32
 IF -----------------------------
    (1)      the task type is intellective [threshold 0.21]
    (2) and the task action is "simple retrieval" [threshold 0.20]
    (3) and the task complexity is "1 variable" [threshold 0.21]
    (4) and the task structure is structured [threshold 0.21]
 THEN ---------------------------
    (1)      tabular recommend is yes [certainty 0.60]

RULE #7 priority 50 - ChD74
 IF -----------------------------
    (1)      the task type is intellective [threshold 0.20]
    (2) and the task action is "simple retrieval" [threshold 0.21]
```

```
     (3) or  the task action is "find relationships" [threshold 0.20]
     (4) and the task complexity is "more than 2 variables" [threshold
0.20]
     (5) and the task structure is "user-defined" [threshold 0.20]
     (6) and the information user functional knowledge is medium
[threshold 0.21]
 THEN ---------------------------
     (1)      tabular recommend is yes [certainty 1.00]
     (2) and statistical transformation recommend is yes [certainty
0.60]

RULE #8 priority 50 - find flagged presentation format objects
 IF -----------------------------
     (1)      the report format recommend is yes [threshold 0.20]
 THEN ---------------------------
     (1)      presentation format recommendations  is objectname(<report
format>) [certainty 1.00]
     (2) and presentation format  is done [certainty 1.00]

RULE #9 priority 50 - find flagged presentation content objects
 IF -----------------------------
     (1)      the report content recommend is yes [threshold 0.20]
 THEN ---------------------------
     (1)      presentation content recommendations  is
objectname(<report content>) [certainty 1.00]
     (2) and presentation content  is done [certainty 1.00]

RULE #10 priority 50 - ChD74
 IF -----------------------------
     (1)      the task type is "problem identification" [threshold 0.20]
     (2) and the task action is "find relationships" [threshold 0.21]
     (3) and the task complexity is "more than 2 variables" [threshold
0.20]
     (4) and the task structure is "user-defined" [threshold 0.20]
     (5) and the information user functional knowledge is high
[threshold 0.21]
 THEN ---------------------------
     (1)      tabular recommend is yes [certainty 0.70]
     (2) and statistical transformation recommend is yes [certainty
0.60]

RULE #11 priority 50 - ChD74
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "simple retrieval" [threshold 0.21]
     (3) or  the task action is "find relationships" [threshold 0.21]
     (4) and the task complexity is "more than 2 variables" [threshold
0.20]
     (5) and the task structure is "user-defined" [threshold 0.20]
     (6) and the information user functional knowledge is high
[threshold 0.21]
 THEN ---------------------------
     (1)      tabular recommend is yes [certainty 0.70]
     (2) and raw data recommend is yes [certainty 0.70]

RULE #12 priority 20 - BaL77
 IF -----------------------------
     (1)      the information user psychological type is "low analytic"
[threshold 0.20]
     (2) or  the information user cognitive complexity is "field
dependent" [threshold 0.20]
 THEN ---------------------------
```

(1) raw data recommend is yes [certainty 0.50]

RULE #13 priority 75 - BeS77
IF ----------------------------
(1) the task type is intellective [threshold 0.20]
(2) and the task action is comparison [threshold 0.20]
(3) or the task action is "trend identification" [threshold 0.20]
(4) and the task complexity is "more than 2 variables" [threshold 0.20]
(5) and the task structure is "user-defined" [threshold 0.20]
THEN ---------------------------
(1) tabular recommend is no [certainty 0.50]
(2) and graphical recommend is yes [certainty 0.50]

RULE #14 priority 75 - BeS77
IF ----------------------------
(1) the task type is intellective [threshold 0.20]
(2) and the task action is "trend identification" [threshold 0.20]
(3) and the task complexity is "more than 2 variables" [threshold 0.20]
(4) and the task structure is "user-defined" [threshold 0.20]
(5) and the information user psychological type is "low analytic" [threshold 0.20]
(6) and the information user functional knowledge is low [threshold 0.20]
THEN ---------------------------
(1) tabular recommend is yes [certainty 0.70]
(2) and graphical recommend is yes [certainty 0.70]
(3) and raw data recommend is yes [certainty 0.70]
(4) and information user information request is high [certainty 0.70]

RULE #15 priority 75 - BeS77
IF ----------------------------
(1) the task type is intellective [threshold 0.20]
(2) and the task action is "trend identification" [threshold 0.21]
(3) or the task action is comparison [threshold 0.20]
(4) and the task complexity is "more than 2 variables" [threshold 0.20]
(5) and the task structure is "user-defined" [threshold 0.20]
(6) and the information user psychological type is "high analytic" [threshold 0.20]
(7) and the information user functional knowledge is high [threshold 0.20]
THEN ---------------------------
(1) tabular recommend is yes [certainty 0.70]
(2) and graphical recommend is yes [certainty 0.70]
(3) and statistical transformation recommend is yes [certainty 0.70]
(4) and information user information request is low [certainty 0.70]

RULE #16 priority 70 - Var77
IF ----------------------------
(1) the task type is planning [threshold 0.20]
(2) and the task action is "trend identification" [threshold 0.21]
(3) and the task complexity is "more than 2 variables" [threshold 0.21]
(4) and the task structure is "user-defined" [threshold 0.21]
(5) and the information user cognitive style is heuristic [threshold 0.20]

(6) and the information user functional knowledge is high [threshold 0.20]
THEN ---------------------------
(1) information user information request is low [certainty 0.70]

RULE #17 priority 40 - Zmu78
IF -----------------------------
(1) the task action is "information extraction" [threshold 0.21]
(2) and the task complexity is "1 variable" [threshold 0.21]
(3) and the task structure is structured [threshold 0.20]
(4) and the information user functional knowledge is medium [threshold 0.20]
(5) or the information user functional knowledge is high [threshold 0.20]
THEN ---------------------------
(1) graphical recommend is yes [certainty 1.00]
(2) and line-based recommend is yes [certainty 1.00]

RULE #18 priority 70 - BeD79
IF -----------------------------
(1) the task type is intellective [threshold 0.20]
(2) and the task action is "trend identification" [threshold 0.21]
(3) or the task action is "simple retrieval" [threshold 0.21]
(4) or the task action is "find relationships" [threshold 0.21]
(5) and the task complexity is "more than 2 variables" [threshold 0.21]
(6) and the task structure is "user-defined" [threshold 0.20]
(7) and the report content structure is structured [threshold 0.20]
(8) and the information user functional knowledge is high [threshold 0.20]
(9) and the information user psychological type is "low analytic" [threshold 0.20]
(10) or the information user cognitive complexity is "field dependent" [threshold 0.20]
(11) and the tabular recommend is yes [threshold 0.20]
THEN ---------------------------
(1) statistical transformation recommend is no [certainty 1.00]
(2) and exception from a standard recommend is no [certainty 1.00]

RULE #19 priority 70 - BeD79
IF -----------------------------
(1) the task type is intellective [threshold 0.20]
(2) and the task action is "trend identification" [threshold 0.21]
(3) or the task action is "simple retrieval" [threshold 0.21]
(4) or the task action is "find relationships" [threshold 0.21]
(5) and the task complexity is "more than 2 variables" [threshold 0.21]
(6) and the task structure is "user-defined" [threshold 0.20]
(7) and the report content structure is structured [threshold 0.20]
(8) and the information user functional knowledge is high [threshold 0.20]
(9) and the information user psychological type is "high analytic" [threshold 0.20]
(10) or the information user cognitive complexity is "field independent" [threshold 0.20]
(11) and the tabular recommend is yes [threshold 0.20]
THEN ---------------------------
(1) statistical transformation recommend is yes [certainty 0.90]

```
RULE #20 priority 70 - BeD79
 IF ----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "trend identification" [threshold 0.21]
     (3) or  the task action is "simple retrieval" [threshold 0.21]
     (4) or  the task action is "find relationships" [threshold 0.21]
     (5) and the task complexity is "more than 2 variables" [threshold
0.21]
     (6) and the task structure is "user-defined" [threshold 0.20]
     (7) and the report content structure is "user-defined" [threshold
0.20]
     (8) and the information user functional knowledge is high
[threshold 0.20]
     (9) and the information user psychological type is "low analytic"
[threshold 0.20]
     (10) or  the information user cognitive complexity is "field
dependent" [threshold 0.20]
     (11) and the tabular recommend is yes [threshold 0.20]
 THEN ---------------------------
     (1)      raw data recommend is yes [certainty 0.90]

RULE #21 priority 70 - BeD79
 IF ----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "trend identification" [threshold 0.21]
     (3) or  the task action is "simple retrieval" [threshold 0.21]
     (4) or  the task action is "find relationships" [threshold 0.21]
     (5) and the task complexity is "more than 2 variables" [threshold
0.21]
     (6) and the task structure is "user-defined" [threshold 0.20]
     (7) and the report content structure is "user-defined" [threshold
0.20]
     (8) and the information user functional knowledge is high
[threshold 0.20]
     (9) and the information user psychological type is "high analytic"
[threshold 0.20]
     (10) or  the information user cognitive complexity is "field
independent" [threshold 0.20]
     (11) and the tabular recommend is yes [threshold 0.20]
 THEN ---------------------------
     (1)      raw data recommend is no [certainty 1.00]

RULE #22 priority 80 - LuK79
 IF ----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is comparison [threshold 0.20]
     (3) or  the task action is "simple retrieval" [threshold 0.20]
     (4) and the task complexity is "1 variable" [threshold 0.20]
     (5) and the task structure is structured [threshold 0.20]
     (6) and the information user functional knowledge is medium
[threshold 0.20]
     (7) and the information user psychological type is "high analytic"
[threshold 0.20]
     (8) or  the information user cognitive complexity is "field
independent" [threshold 0.20]
     (9) and the information user format experience is tabular
[threshold 0.20]
     (10) and the information user content experience is "raw data"
[threshold 0.20]
     (11) and the tabular recommend is yes [threshold 0.20]
 THEN ---------------------------
     (1)      raw data recommend is yes [certainty 0.90]
```

(2) and statistical transformation recommend is yes [certainty 0.80]

RULE #23 priority 80 - LuK79
IF ----------------------------
(1) the task type is intellective [threshold 0.20]
(2) and the task action is comparison [threshold 0.20]
(3) or the task action is "simple retrieval" [threshold 0.20]
(4) and the task complexity is "1 variable" [threshold 0.20]
(5) and the task structure is structured [threshold 0.20]
(6) and the information user functional knowledge is medium [threshold 0.20]
(7) and the information user psychological type is "high analytic" [threshold 0.20]
(8) or the information user cognitive complexity is "field independent" [threshold 0.20]
(9) and the information user format experience is tabular [threshold 0.20]
(10) and the information user content experience is "raw data" [threshold 0.20]
THEN ---------------------------
(1) graphical recommend is no [certainty 0.60]
(2) and grouped bar chart recommend is no [certainty 0.60]
(3) and line-based recommend is no [certainty 0.60]
(4) and statistical transformation recommend is yes [certainty 0.80]

RULE #24 priority 80 - LuK79
IF ----------------------------
(1) the task type is intellective [threshold 0.20]
(2) and the task action is comparison [threshold 0.20]
(3) or the task action is "simple retrieval" [threshold 0.20]
(4) and the task complexity is "1 variable" [threshold 0.20]
(5) and the task structure is structured [threshold 0.20]
(6) and the information user functional knowledge is medium [threshold 0.20]
(7) and the information user psychological type is "low analytic" [threshold 0.20]
(8) or the information user cognitive complexity is "field dependent" [threshold 0.20]
(9) and the information user format experience is tabular [threshold 0.20]
(10) and the information user content experience is "raw data" [threshold 0.20]
(11) and the tabular recommend is yes [threshold 0.20]
THEN ---------------------------
(1) raw data recommend is yes [certainty 0.80]
(2) and statistical transformation recommend is yes [certainty 0.90]
(3) and statistical transformation recommend is yes [certainty 0.80]

RULE #25 priority 60 - Dav81
IF ----------------------------
(1) the task type is intellective [threshold 0.20]
(2) and the task action is "find relationships" [threshold 0.21]
(3) or the task action is "simple retrieval" [threshold 0.21]
(4) and the task complexity is "more than 2 variables" [threshold 0.20]
(5) and the information user functional knowledge is medium [threshold 0.20]
THEN ---------------------------

```
     (1)      raw data recommend is yes [certainty 0.60]
     (2) and tabular recommend is yes [certainty 0.60]
     (3) and simple bar chart recommend is yes [certainty 0.60]

RULE #26 priority 60 - Dav81
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "find relationships" [threshold 0.21]
     (3) or  the task action is "simple retrieval" [threshold 0.21]
     (4) and the task complexity is "more than 2 variables" [threshold
0.20]
     (5) and the information user functional knowledge is medium
[threshold 0.20]
     (6) and the information user cognitive type is "sensing-thinking"
[threshold 0.20]
 THEN ---------------------------
     (1)      raw data recommend is yes [certainty 1.00]
     (2) and simple bar chart recommend is yes [certainty 1.00]

RULE #27 priority 60 - Dav81
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "find relationships" [threshold 0.21]
     (3) or  the task action is "simple retrieval" [threshold 0.21]
     (4) and the task complexity is "more than 2 variables" [threshold
0.20]
     (5) and the information user functional knowledge is medium
[threshold 0.20]
     (6) and the information user cognitive type is "sensing-feeling"
[threshold 0.20]
 THEN ---------------------------
     (1)      raw data recommend is yes [certainty 0.90]
     (2) and statistical transformation recommend is yes [certainty
0.90]
     (3) and tabular recommend is yes [certainty 0.90]

RULE #28 priority 60 - Dav81
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "find relationships" [threshold 0.21]
     (3) or  the task action is "simple retrieval" [threshold 0.21]
     (4) and the task complexity is "more than 2 variables" [threshold
0.20]
     (5) and the information user functional knowledge is medium
[threshold 0.20]
     (6) and the information user cognitive type is "intuitive-thinking"
[threshold 0.20]
 THEN ---------------------------
     (1)      raw data recommend is no [certainty 0.60]
     (2) and tabular recommend is no [certainty 0.60]

RULE #29 priority 60 - Dav81
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "find relationships" [threshold 0.21]
     (3) or  the task action is "simple retrieval" [threshold 0.21]
     (4) and the task complexity is "more than 2 variables" [threshold
0.20]
     (5) and the information user functional knowledge is medium
[threshold 0.20]
     (6) and the information user cognitive type is "intuitive-feeling"
[threshold 0.20]
```

```
 THEN ---------------------------
     (1)      raw data recommend is yes [certainty 1.00]
     (2) and tabular recommend is yes [certainty 1.00]

RULE #30 priority 60 - Dav81
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "find relationships" [threshold 0.21]
     (3) or  the task action is "simple retrieval" [threshold 0.21]
     (4) and the task complexity is "more than 2 variables" [threshold
0.20]
     (5) and the information user functional knowledge is medium
[threshold 0.20]
     (6) and the information user cognitive type is "intuitive-feeling"
[threshold 0.20]
 THEN ---------------------------
     (1)      simple bar chart recommend is yes [certainty 1.00]
     (2) and statistical transformation recommend is yes [certainty
1.00]

RULE #31 priority 60 - Gha81
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "find relationships" [threshold 0.21]
     (3) or  the task action is "simple retrieval" [threshold 0.21]
     (4) and the task complexity is "more than 2 variables" [threshold
0.21]
     (5) and the information user functional knowledge is medium
[threshold 0.20]
     (6) and the information user cognitive type is "intuitive-feeling"
[threshold 0.20]
     (7) or  the information user cognitive type is "sensing-feeling"
[threshold 0.20]
 THEN ---------------------------
     (1)      graphical recommend is yes [certainty 0.50]

RULE #32 priority 60 - Gha81
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "find relationships" [threshold 0.21]
     (3) or  the task action is "simple retrieval" [threshold 0.21]
     (4) and the task complexity is "more than 2 variables" [threshold
0.21]
     (5) and the information user functional knowledge is medium
[threshold 0.20]
     (6) and the information user cognitive type is "sensing-thinking"
[threshold 0.20]
     (7) or  the information user cognitive type is "intuitive-thinking"
[threshold 0.20]
 THEN ---------------------------
     (1)      tabular recommend is yes [certainty 0.50]

RULE #33 priority 40 - Gha81
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "simple retrieval" [threshold 0.20]
     (3) and the task complexity is "more than 2 variables" [threshold
0.21]
     (4) and the information user functional knowledge is medium
[threshold 0.20]
 THEN ---------------------------
     (1)      tabular recommend is yes [certainty 0.50]
```

```
RULE #34 priority 40 - Gha81
 IF ------------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "find relationships" [threshold 0.20]
     (3) and the task complexity is "more than 2 variables" [threshold
0.21]
     (4) and the information user functional knowledge is medium
[threshold 0.20]
 THEN ----------------------------
     (1)      graphical recommend is yes [certainty 0.50]

RULE #35 priority 10 - Luc81
 IF ------------------------------
     (1)      the task type is "problem identification" [threshold 0.20]
 THEN ----------------------------
     (1)      line-based recommend is yes [certainty 0.50]

RULE #36 priority 70 - Luc81
 IF ------------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "simple retrieval" [threshold 0.21]
     (3) or  the task action is "find relationships" [threshold 0.21]
     (4) and the task complexity is "more than 2 variables" [threshold
0.21]
     (5) and the task structure is structured [threshold 0.20]
     (6) and the information user functional knowledge is high
[threshold 0.20]
     (7) and the information user cognitive style is heuristic
[threshold 0.20]
 THEN ----------------------------
     (1)      graphical recommend is yes [certainty 1.00]
     (2) and raw data recommend is yes [certainty 1.00]

RULE #37 priority 60 - GeS82
 IF ------------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "simple retrieval" [threshold 0.20]
     (3) or  the task action is recall [threshold 0.20]
     (4) and the task structure is structured [threshold 0.20]
     (5) and the report content structure is "user-defined" [threshold
0.20]
     (6) and the information user functional knowledge is high
[threshold 0.20]
 THEN ----------------------------
     (1)      tabular recommend is yes [certainty 1.00]

RULE #38 priority 70 - OtD82
 IF ------------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "find relationships" [threshold 0.20]
     (3) and the task structure is "user-defined" [threshold 0.20]
     (4) and the task complexity is "more than 2 variables" [threshold
0.20]
     (5) and the information user cognitive complexity is "field
independent" [threshold 0.20]
     (6) and the information user functional knowledge is medium
[threshold 0.21]
 THEN ----------------------------
     (1)      information user information request is high [certainty
0.60]

RULE #39 priority 30 - WaD83
```

```
 IF -----------------------------
     (1)      the task action is recall [threshold 0.20]
     (2) and the information user functional knowledge is medium
[threshold 0.20]
 THEN ---------------------------
     (1)      tabular recommend is yes [certainty 0.50]
     (2) and three d chart recommend is yes [certainty 0.50]

RULE #40 priority 70 - ZBM83
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "information extraction" [threshold
0.21]
     (3) and the task structure is structured [threshold 0.20]
     (4) and the task complexity is low [threshold 0.20]
     (5) and the information user functional knowledge is high
[threshold 0.20]
 THEN ---------------------------
     (1)      grouped bar chart recommend is yes [certainty 1.00]
     (2) and raw data recommend is yes [certainty 1.00]

RULE #41 priority 70 - ZBM83
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "information extraction" [threshold
0.21]
     (3) and the task structure is structured [threshold 0.20]
     (4) and the task complexity is high [threshold 0.20]
     (5) and the information user functional knowledge is high
[threshold 0.20]
 THEN ---------------------------
     (1)      grouped bar chart recommend is no [certainty 1.00]
     (2) and raw data recommend is no [certainty 1.00]

RULE #42 priority 60 - ZBM83
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "information extraction" [threshold
0.21]
     (3) and the task structure is structured [threshold 0.20]
     (4) and the information user quantitative ability is high
[threshold 0.20]
     (5) and the information user functional knowledge is high
[threshold 0.20]
 THEN ---------------------------
     (1)      tabular recommend is yes [certainty 0.70]
     (2) and raw data recommend is yes [certainty 0.70]

RULE #43 priority 70 - ZBM83
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "information extraction" [threshold
0.21]
     (3) and the task structure is structured [threshold 0.20]
     (4) and the information user work experience is high [threshold
0.20]
     (5) and the information user functional knowledge is high
[threshold 0.20]
 THEN ---------------------------
     (1)      grouped bar chart recommend is yes [certainty 0.70]
     (2) and raw data recommend is yes [certainty 0.70]
```

```
RULE #44 priority 50 - Reu84
 IF ----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "simple retrieval" [threshold 0.21]
     (3) or  the task action is "find relationships" [threshold 0.21]
     (4) and the task structure is "user-defined" [threshold 0.20]
     (5) and the task complexity is "more than 2 variables" [threshold
0.20]
     (6) and the information user functional knowledge is low [threshold
0.20]
 THEN --------------------------
     (1)      tabular recommend is yes [certainty 0.50]
     (2) and raw data recommend is yes [certainty 0.50]

RULE #45 priority 70 - BeD85
 IF ----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "simple retrieval" [threshold 0.20]
     (3) or  the task action is "find relationships" [threshold 0.20]
     (4) or  the task action is "information extraction" [threshold
0.20]
     (5) and the task structure is "user-defined" [threshold 0.20]
     (6) and the task complexity is "more than 2 variables" [threshold
0.20]
     (7) and the information user functional knowledge is high
[threshold 0.20]
     (8) or  the information user functional knowledge is medium
[threshold 0.20]
 THEN --------------------------
     (1)      tabular recommend is yes [certainty 0.50]
     (2) and raw data recommend is yes [certainty 0.50]
     (3) and line-based recommend is yes [certainty 0.50]

RULE #46 priority 70 - BeD85-2
 IF ----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "simple retrieval" [threshold 0.20]
     (3) or  the task action is "find relationships" [threshold 0.20]
     (4) or  the task action is "information extraction" [threshold
0.20]
     (5) and the task structure is "user-defined" [threshold 0.20]
     (6) and the task complexity is "more than 2 variables" [threshold
0.20]
     (7) and the information user functional knowledge is high
[threshold 0.20]
     (8) or  the information user functional knowledge is medium
[threshold 0.20]
     (9) and the information user cognitive complexity is "field
dependent" [threshold 0.20]
 THEN --------------------------
     (1)      tabular recommend is yes [certainty 0.50]
     (2) and recommendation color is color [certainty 0.60]
     (3) and graphical recommend is no [certainty 0.60]

RULE #47 priority 60 - DDM86-1  ex1
 IF ----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "simple retrieval" [threshold 0.21]
     (3) or  the task action is comparison [threshold 0.21]
     (4) and the task structure is structured [threshold 0.20]
     (5) and the task complexity is "1 variable" [threshold 0.20]
```

(6) and the information user functional knowledge is high [threshold 0.20]
THEN ---------------------------
(1) tabular recommend is yes [certainty 0.50]
(2) and graphical recommend is yes [certainty 0.50]

RULE #48 priority 60 - DDM86-2 ex2
IF ----------------------------
(1) the task type is planning [threshold 0.20]
(2) and the task action is "simple retrieval" [threshold 0.20]
(3) or the task action is "trend identification" [threshold 0.20]
(4) or the task action is comparison [threshold 0.21]
(5) and the task structure is "user-defined" [threshold 0.20]
(6) and the task complexity is "2 variables" [threshold 0.20]
(7) and the information user functional knowledge is medium [threshold 0.20]
THEN ---------------------------
(1) tabular recommend is yes [certainty 0.50]
(2) and graphical recommend is yes [certainty 0.70]

RULE #49 priority 60 - DDM86-3 ex2
IF ----------------------------
(1) the task type is planning [threshold 0.20]
(2) and the task action is "trend identification" [threshold 0.20]
(3) and the task structure is "user-defined" [threshold 0.20]
(4) and the task complexity is "2 variables" [threshold 0.20]
THEN ---------------------------
(1) tabular recommend is no [certainty 1.00]
(2) and graphical recommend is yes [certainty 1.00]

RULE #50 priority 60 - DDM86-4 ex3
IF ----------------------------
(1) the task type is intellective [threshold 0.20]
(2) or the task action is recall [threshold 0.20]
(3) and the task structure is "user-defined" [threshold 0.20]
(4) and the task complexity is "more than 2 variables" [threshold 0.20]
(5) and the tabular recommend is yes [threshold 0.20]
THEN ---------------------------
(1) information user information request is low [certainty 1.00]

RULE #51 priority 60 - DDM86-5 ex3
IF ----------------------------
(1) the task type is intellective [threshold 0.20]
(2) and the task action is recall [threshold 0.20]
(3) and the task structure is "user-defined" [threshold 0.20]
(4) and the task complexity is "more than 2 variables" [threshold 0.20]
(5) and the information user functional knowledge is medium [threshold 0.20]
(6) and the graphical recommend is yes [threshold 0.20]
THEN ---------------------------
(1) information user information request is high [certainty 1.00]
(2) and raw data recommend is yes [certainty 1.00]

RULE #52 priority 50 - DDM86-6 ex3
IF ----------------------------
(1) the task type is intellective [threshold 0.20]
(2) and the task action is recall [threshold 0.20]
(3) or the task action is "simple retrieval" [threshold 0.20]

(4) and the task complexity is "more than 2 variables" [threshold 0.20]
(5) and the information user functional knowledge is medium [threshold 0.20]
(6) and the information user information request is high [threshold 0.20]
(7) or the recommendation information volume is high [threshold 0.20]
THEN ----------------------------
(1) recommendation information volume is "split into subsets" [certainty 1.00]
(2) and raw data recommend is yes [certainty 1.00]

RULE #53 priority 20 - DDM86-7
IF ------------------------------
(1) the task action is recall [threshold 0.20]
(2) or the task action is "trend identification" [threshold 0.20]
(3) and the task complexity is "more than 2 variables" [threshold 0.20]
(4) and the information user information request is high [threshold 0.20]
(5) or the recommendation information volume is high [threshold 0.20]
THEN ----------------------------
(1) graphical recommend is yes [certainty 0.70]

RULE #54 priority 40 - Lau87-1
IF ------------------------------
(1) the task type is intellective [threshold 0.20]
(2) or the task action is comparison [threshold 0.21]
(3) and the task complexity is "more than 2 variables" [threshold 0.20]
(4) and the task structure is structured [threshold 0.20]
THEN ----------------------------
(1) graphical recommend is yes [certainty 0.70]
(2) and grouped bar chart recommend is yes [certainty 0.70]
(3) and line-based recommend is yes [certainty 1.00]

RULE #55 priority 40 - Lau87-2
IF ------------------------------
(1) the task type is intellective [threshold 0.20]
(2) and the task action is "information extraction" [threshold 0.20]
(3) or the task action is comparison [threshold 0.21]
(4) or the task action is "find relationships" [threshold 0.21]
(5) and the task complexity is "more than 2 variables" [threshold 0.20]
(6) and the task structure is structured [threshold 0.20]
THEN ----------------------------
(1) graphical recommend is yes [certainty 0.70]
(2) and pie chart recommend is yes [certainty 0.70]

RULE #56 priority 40 - Lau87-3
IF ------------------------------
(1) the task type is intellective [threshold 0.20]
(2) and the task action is "simple retrieval" [threshold 0.21]
(3) or the task action is "find relationships" [threshold 0.20]
(4) and the task complexity is "more than 2 variables" [threshold 0.20]
(5) and the task structure is structured [threshold 0.20]
THEN ----------------------------
(1) tabular recommend is yes [certainty 0.70]

```
RULE #57 priority 60 - Reu87-1
 IF ----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "simple retrieval" [threshold 0.21]
     (3) or  the task action is "find relationships" [threshold 0.21]
     (4) and the task complexity is "more than 2 variables" [threshold
0.20]
     (5) and the task structure is "user-defined" [threshold 0.20]
     (6) and the task environmental complexity is medium [threshold
0.20]
     (7) or  the task environmental complexity is high [threshold 0.22]
     (8) and the information user functional knowledge is high
[threshold 0.20]
 THEN --------------------------
     (1)      graphical recommend is yes [certainty 0.80]
     (2) and line-based recommend is yes [certainty 0.80]

RULE #58 priority 60 - Reu87-2
 IF ----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "simple retrieval" [threshold 0.21]
     (3) or  the task action is "find relationships" [threshold 0.21]
     (4) and the task complexity is "more than 2 variables" [threshold
0.20]
     (5) and the task structure is "user-defined" [threshold 0.20]
     (6) and the task environmental complexity is low [threshold 0.20]
     (7) and the information user functional knowledge is high
[threshold 0.20]
 THEN --------------------------
     (1)      tabular recommend is yes [certainty 0.80]

RULE #59 priority 70 - DoB88-1
 IF ----------------------------
     (1)      the task type is "problem identification" [threshold 0.21]
     (2) or  the task type is "problem prioritization" [threshold 0.21]
     (3) or  the task action is "find relationships" [threshold 0.21]
     (4) and the task complexity is "more than 2 variables" [threshold
0.20]
     (5) and the task structure is "user-defined" [threshold 0.20]
     (6) and the information user functional knowledge is medium
[threshold 0.20]
 THEN --------------------------
     (1)      tabular recommend is yes [certainty 1.00]
     (2) and change from base case recommend is yes [certainty 1.00]

RULE #60 priority 60 - DoB88-2
 IF ----------------------------
     (1)      the task type is "problem identification" [threshold 0.21]
     (2) and the task complexity is "more than 2 variables" [threshold
0.20]
     (3) and the task structure is "user-defined" [threshold 0.20]
     (4) and the information user functional knowledge is medium
[threshold 0.20]
 THEN --------------------------
     (1)      tabular recommend is no [certainty 1.00]
     (2) and exception from a standard recommend is no [certainty 1.00]

RULE #61 priority 60 - UmS88-1 ex1
 IF ----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "trend identification" [threshold 0.20]
     (3) or  the task action is "find relationships" [threshold 0.20]
```

```
     (4) or  the task action is recall [threshold 0.20]
     (5) and the task complexity is "1 variable" [threshold 0.20]
     (6) and the task response time is important [threshold 0.20]
     (7) and the task structure is structured [threshold 0.20]
     (8) and the information user functional knowledge is high
[threshold 0.20]
 THEN ---------------------------
     (1)     graphical recommend is yes [certainty 0.80]
     (2) and simple bar chart recommend is yes [certainty 0.80]
     (3) and raw data recommend is yes [certainty 0.80]

RULE #62 priority 65 - UmS88-2 ex2
 IF -----------------------------
     (1)     the task type is intellective [threshold 0.20]
     (2) and the task action is comparison [threshold 0.20]
     (3) or  the task action is "simple retrieval" [threshold 0.20]
     (4) or  the task action is recall [threshold 0.20]
     (5) and the task complexity is "1 variable" [threshold 0.20]
     (6) and the task response time is important [threshold 0.20]
     (7) and the task structure is structured [threshold 0.20]
     (8) and the information user functional knowledge is high
[threshold 0.20]
     (9) and the information user format experience is tabular
[threshold 0.20]
     (10) or  the information user format experience is graphical
[threshold 0.20]
 THEN ---------------------------
     (1)     graphical recommend is yes [certainty 1.00]
     (2) and simple bar chart recommend is yes [certainty 1.00]
     (3) and raw data recommend is yes [certainty 1.00]
     (4) and tabular recommend is yes [certainty 1.00]

RULE #63 priority 65 - UmS88-3 ex2
 IF -----------------------------
     (1)     the task type is intellective [threshold 0.20]
     (2) and the task action is "trend identification" [threshold 0.20]
     (3) or  the task action is "find relationships" [threshold 0.20]
     (4) or  the task action is recall [threshold 0.20]
     (5) and the task complexity is "1 variable" [threshold 0.20]
     (6) and the task response time is important [threshold 0.20]
     (7) and the task structure is structured [threshold 0.20]
     (8) and the information user functional knowledge is high
[threshold 0.20]
     (9) and the information user format experience is graphical
[threshold 0.20]
     (10) or  the information user format experience is tabular
[threshold 0.20]
 THEN ---------------------------
     (1)     graphical recommend is yes [certainty 1.00]
     (2) and simple bar chart recommend is yes [certainty 1.00]
     (3) and raw data recommend is yes [certainty 1.00]

RULE #64 priority 70 - GLR89-1
 IF -----------------------------
     (1)     the task type is intellective [threshold 0.20]
     (2) and the task action is comparison [threshold 0.20]
     (3) and the task complexity is "1 variable" [threshold 0.20]
     (4) and the task response time is important [threshold 0.20]
     (5) and the task structure is structured [threshold 0.20]
     (6) and the information user functional knowledge is high
[threshold 0.20]
 THEN ---------------------------
```

```
     (1)      graphical recommend is yes [certainty 0.80]
     (2) and line-based recommend is yes [certainty 0.80]
     (3) and area-based recommend is yes [certainty 0.80]
     (4) and raw data recommend is yes [certainty 0.80]

RULE #65 priority 70 - GLR89-2
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "simple retrieval" [threshold 0.20]
     (3) and the task complexity is "1 variable" [threshold 0.20]
     (4) and the task response time is important [threshold 0.20]
     (5) and the task structure is structured [threshold 0.20]
     (6) and the information user functional knowledge is high
[threshold 0.20]
 THEN ---------------------------
     (1)      graphical recommend is yes [certainty 0.80]
     (2) and point-based recommend is yes [certainty 0.80]
     (3) and raw data recommend is yes [certainty 0.80]

RULE #66 priority 55 - GLR89-3
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "simple retrieval" [threshold 0.20]
     (3) or  the task action is comparison [threshold 0.20]
     (4) and the task complexity is "1 variable" [threshold 0.20]
     (5) and the task response time is important [threshold 0.20]
     (6) and the task structure is structured [threshold 0.20]
     (7) and the information user functional knowledge is high
[threshold 0.20]
 THEN ---------------------------
     (1)      graphical recommend is yes [certainty 0.70]
     (2) and area-based recommend is yes [certainty 0.70]
     (3) and three d chart recommend is yes [certainty 0.70]

RULE #67 priority 50 - Dav85
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "simple retrieval" [threshold 0.20]
     (3) and the task complexity is "1 variable" [threshold 0.20]
 THEN ---------------------------
     (1)      table recommend is yes [certainty 0.70]

RULE #68 priority 50 - Dav85
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "simple retrieval" [threshold 0.20]
     (3) or  the task action is comparison [threshold 0.20]
     (4) and the task complexity is "1 variable" [threshold 0.20]
 THEN ---------------------------
     (1)      grouped bar chart recommend is yes [certainty 0.70]
     (2) and line chart recommend is yes [certainty 0.70]

RULE #69 priority 50 - Dav85
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "information extraction" [threshold
0.20]
     (3) or  the task action is comparison [threshold 0.20]
     (4) and the task complexity is "2 variables" [threshold 0.20]
 THEN ---------------------------
     (1)      grouped bar chart recommend is yes [certainty 0.70]
```

```
RULE #70 priority 50 - Dav85
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "information extraction" [threshold
0.20]
     (3) or  the task action is comparison [threshold 0.20]
     (4) or  the task action is "simple retrieval" [threshold 0.20]
     (5) and the task complexity is "1 variable" [threshold 0.20]
 THEN ---------------------------
     (1)      pie chart recommend is yes [certainty 0.70]

RULE #71 priority 50 - Dav85
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) and the task action is "information extraction" [threshold
0.20]
     (3) or  the task action is comparison [threshold 0.20]
     (4) or  the task action is "simple retrieval" [threshold 0.20]
     (5) and the task complexity is "1 variable" [threshold 0.20]
 THEN ---------------------------
     (1)      tabular recommend is yes [certainty 0.70]

RULE #72 priority 50 - Dav85
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) or  the task action is comparison [threshold 0.20]
     (3) and the task complexity is "more than 2 variables" [threshold
0.20]
 THEN ---------------------------
     (1)      tabular recommend is yes [certainty 0.70]

RULE #73 priority 50 - Dav85
 IF -----------------------------
     (1)      the task type is intellective [threshold 0.20]
     (2) or  the task action is comparison [threshold 0.20]
     (3) and the task complexity is "more than 2 variables" [threshold
0.20]
 THEN ---------------------------
     (1)      line chart recommend is yes [certainty 0.60]

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INFORMEX: AN EXPERT SYSTEM TO ENHANCE INFORMATION PRESENTATION

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ABSTRACT

The proliferation of information systems in organizations allowed companies to capture and store volumes of operational strategic information. Unfortunately, most companies lack a systematic way to convert this wealth of data into a useful information format for decision makers. Artificial intelligence technologies provide a promising vehicle for improving this information flow dilemma.

Studies and experiments conducted by industrial engineers, management scientists, and industrial psychologist have addressed the presentation question. This research suggests that the **mode of information presentation** (i.e., tabular, graphical, summarized, detailed, etc.) should be suited to the **task environment** of the decision (i.e., planning, intellective selection, preferential selection, etc.) and the **individual characteristics** of the decision maker (i.e., analytic style, functional knowledge, system familiarity, etc.).

This paper documents an expert system for improving the quality of the MIS output. It embodies a knowledge base of relationships among presentation mode, task environment, and individual characteristics of the decision maker. The system can be consulted by an information systems professional to improve presentation format and content.

1. INTRODUCTION

Organizations have recognized that quality information is a precursor for sound managerial decision making. They have addressed this need by developing elaborate information systems for management. For many managers, these systems produce either "too much" or "not enough" information [Chervany and Dickson 1974][Ackoff 1967][Vasarhelyi 1977]. Some managers drown in voluminous output that adds little real value to their decision process, while other managers receive too few inputs or are given information in an inappropriate form which they cannot use.

Researchers have attempted to resolve this dilemma by investigating how information should be presented. Specifically, they have sought to identify the appropriate information presentation format and content for managerial decision makers. Much research by MIS professionals, management scientists, industrial engineers, and social scientists has tried to determine if more effective and efficient decisions are made when the task, presentation format, and individual characteristics are in concert.

Others have reviewed the empirical investigation of the presentation question: Dickson, Senn, and Chervany [Dickson et al. 1977], Zmud [Zmud 1979], DeSancitis [DeSanctis 1984], and Jarvenpaa, Dickson, and DeSanctis [Jarvenpaa et al. 1985]. The objective of these reviews has often been to identify conceptual or methodological problems in the research or to support a particular directive for future work. While these reviews have been helpful in condensing a broad body of research, unfortunately they have not compiled the specific research findings in a form useful to those charged with driving a company's information system. The objective of this project is to develop an expert system to recommend information presentation format and content based on the results of empirical research.

1.1 Knowledge-Based Systems

Artificial intelligence (AI) differs from conventional computer programming methodologies in its ability to represent and solve problems symbolically, rather than numerically. Rule-based systems are a subfield of AI that attempts to represent knowledge and human expertise in rules or IF-THEN statements. While such rule-based systems are commonly known as expert systems, a distinction can be made between true expert systems and knowledge-based systems. Knowledge-based systems represent academic knowledge about a problem and contain limited heuristic abilities, while true expert systems incorporate extensive human expertise and intuition along with the academic knowledge [Rauch 1988]. Rule-based systems have been heralded for their ability to "preserve and disseminate scarce expertise" [Luconi et al. 1986]. Many companies including Digital Equipment Corporation [Barker 1989] and Tektronix [Sayles and Thomas 1988] have documented successful uses of rule-based systems in this capacity.

1.2 Artificial Intelligence Applications in MIS

The popular and academic literature continues to document the increasingly broad application of knowledge-based and expert systems to many business problems. Unfortunately, few MIS departments, though often saddled with a multiple year application development/maintenance backlog, have mimicked this success in applying artificial intelligence to solve their own problems. In the relatively few documented cases of AI for MIS, little has been done to enhance the quality of the MIS output. Usually, increasing the MIS department's productivity has been the primary objective. The traditional software development cycle has been indicted as a key factor in the MIS application development backlog [Samson 1987]. Recent projects have sought to use knowledge-based systems to aid in rapid prototyping of applications and to actually generate program code. In an overview of commercial applications for software development, Rauch-Hindin [Rauch 1988] recommends the use of AI in MIS development when the problem is logically complex, will require frequent application maintenance, or when applications must be custom tailored for multiple users or departments.

While these applications are making the MIS department more productive in application development and processing, AI has not yet been applied to improve the quality and usability of the MIS output. INFORMEX (INFORMation EXpert) is a knowledge-based system for the MIS department. It addresses the logically complex problem of presentation format and content selection and will be the knowledge vehicle for the body of research findings in this field. INFORMEX will be consulted by systems analysts and others who prepare the outputs from an information system.

Knowledge-based expert system technology has been successfully applied to a somewhat parallel problem in marketing. Rangaswamy, et al. [Rangaswamy et al. 1989] used a body of research literature and professional judgments to construct

NEGOTEX, an international negotiations expert system. The system asks questions about the proposed negotiations, such as the nationalities of the negotiators, relative decision power, and desired outcomes, and makes recommendations about meeting location, negotiation strategy, and pre-meeting communication. The system has over 350 rules and has limited its focus to rules for American, Japanese, and Chinese negotiators.

The concept of using artificial intelligence technologies to recommend presentation format and content is a suitable domain for knowledge systems. The problem is semistructured with distinctly identifiable factors (individual, task, and presentation) that can be checked against known research findings (knowledge) to derive a recommendation. INFORMEX will serve as the dissemination vehicle for the body of knowledge that relates these factors. It enquires about the target information system OUTPUT (i.e., report or screen display), the individual DECISION MAKER CHARACTERISTICS (target user), and the type of TASK. Through the use of heuristic reasoning, INFORMEX compares these inputs to its knowledge base of research findings and heuristic "rules of thumb" to recommend a presentation format and information content. A sample INFORMEX recommendation might suggest vertically grouped bar charts, statistically summarized, and presented as a deviation from a standard value.

A second objective, a by-product of this effort, is to unify the results of what has been learned from previous experiments and to identify the gaps in our knowledge about information presentation.

2. DEVELOPMENT OF THE KNOWLEDGE BASE

The knowledge base represents the rules that the system will use to make its judgments, and the construction of an accurate knowledge base is the founding task of building an expert system [Edosomwan 1987]. Usually rules for expert systems derived from systematic interviews with multiple "experts" in the field. In a relatively young research field, this luxury is not available nor can an all-knowing expert be interviewed. Therefore, documented experiments in academic journals served as the primary domain expert. Twenty-nine studies, some including multiple experiments, were identified based on their inclusion in one of the major literature review papers [Dickson et al. 1977][Zmud79][Huber 1983][DeSanctis 1984], recent publication, or unique contribution to the field. Some of these experiments have been criticized for possible methodological flaws [Jarvenpaa 1985] as well as inconclusive evidence [Huber 1983]. However, INFORMEX is not overly concerned with methodological problems, but rather with the delivery and application of what has been learned from this research.

The second source of knowledge can be professional judgments of information systems professionals and MIS faculty. The rules from these sources will receive a lower certainty rating in the knowledge base. The present version of INFORMEX does not include such judgments.

Figure 1 depicts the conceptual model for INFORMEX and shows how three research areas will be integrated to improve presentation format and content. The figure also lists the individual, task, and format variables that are incorporated in INFORMEX.

Each of the reviewed empirical studies was summarized in a short text document. They were categorized by the types of variables (task, individual, format and content) that were operationalized in the study and the findings of the study. These summaries provide the body of the explanation facility for INFORMEX's conclusions.

Because of the great diversity of terminology and research designs used in the literature, extracting consistent rules from the studies proved to be a formidable task. Consistency in terminology had to be developed between the studies' variables and findings. After several unsuccessful attempts at extracting rules, a rule worksheet was developed to help standardize the terminology.

The worksheet was developed by listing all of the types of variables and attribute values that had been included in any study. This list was refined to include the more frequently used variables and attribute values. A sample worksheet is shown in Figure 2. Each study was reviewed again and the appropriate attribute variables were circled on the worksheet to form a rule. For example, a study might include an intellective task requiring a decision maker to consider two variables and compare several alternatives. Each of these would be circled on the rule worksheet along with the experimental findings. If the study reported that high analytics performed better with tabular raw data, these results would be circled in the recommendation section of the rule worksheet. A second rule with the same independent variables (intellective, 2

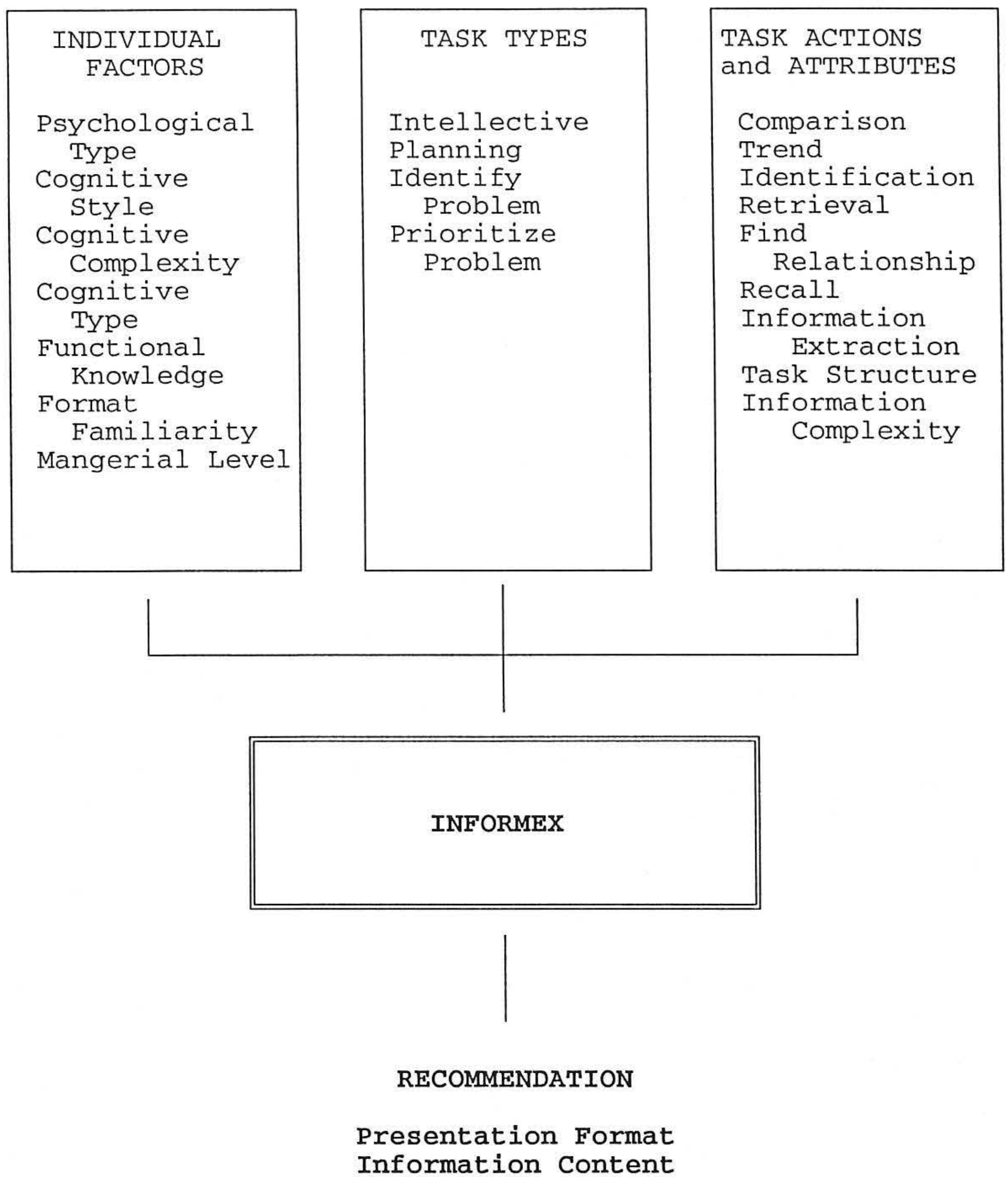

Figure 1. Conceptual Model

		INDIVIDUAL COGNITIVE FACTORS (2)			
TASK (1) TYPE	**TASK (1) ACTIONS**	**PSYCHOLOGICAL TYPE**	**COGNITIVE STYLE**	**COGNITIVE TYPE**	**COGNITIVE COMPLEXITY**
Intellective Planning Training Problem Identification Problem Prioritization	Comparison Trend Identification Simple Retrieval Find Relationships Recall Information Extraction	High Analytic Low Analytic	Analytic Heuristic	Sensing-Thinking Sensing-Feeling Intuitive-Thinking Intuitive-Feeling	Field Dependent Field Independent

FUNCTIONAL (1) KNOWLEDGE	**RESPONSE (.5) TIME**	**RETENTION (.5) REQUIREMENTS**	**INFORMATION (1) COMPLEXITY**		**TASK (1) STRUCTURE**
High Medium Low	Important Not Important	Important Not Important	1 Variable 2 Variables More than Two		Structured User-Defined

USER FAMILIARITY WITH FORMAT (.5)	**USER FAMILIARITY WITH CONTENT (.5)**	**TABULAR**	**GRAPHICAL**	**SPECIFIC FORMAT**	**REPORT CONTENT**
Tabular Graphical Grouped Bar Column Pie Star Area Line Segmented Bar Three-D Scatter Plot Simple Bar Bubble	Change from Base Case Exception from a Standard Raw Data Statistical Transformation	Yes No	Yes No	Grouped Bar Column Pie Star Area Line Segmented Bar Three-D Scatter Plot Simple Bar Bubble	Change from Base Case Exception from a Standard Raw Data Statistical Transformation

RULE PRIORITY: 1 2 3 4 5 6 7 8 9 10

CERTAINTY: .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0

Figure 2. Sample Rule Worksheet

variables, etc.) would be recorded if the study also concluded that low analytics performed better with statistically transformed graphs. A separate worksheet was completed for each rule.

Since expert systems also allow rules to be prioritized and weighted for certainty, each rule was ranked based on the following criteria. Higher priorities were assigned to rules with more methodological richness, which we defined as the explicit inclusion of more categories of variables. The finding from a study that investigated a planning task type, specified comparison and recall task actions, and qualified the users by cognitive complexity and level of functional knowledge would receive a higher priority than a finding where only the task was identified and no individual measures were used. These priorities were scored from 1 to 10 based on the weights noted in parenthesis in Figure 2. The certainty of a rule's conclusion is based on the statistical significance of the experimental results. Findings that were significant at the .01 level received a certainty rating of 1. Those significant at .05 received a .7 rating and the finding that only supported directionalities received a .5. Non-empirical judgments of MIS faculty and professionals received a .4.

When the description of the experimental environment or the results in the paper were difficult to interpret, more than one person independently reviewed the study and independently completed rule worksheets. The authors then discussed these worksheets and combined them into a production rule.

3. FUNCTIONAL DESCRIPTION OF INFORMEX

3.1 Scope

The present INFORMEX system is a stand-alone personal computer version that runs on DOS based machines. It has a generic focus (not tailored to any one industry or firm) and should be able to assist with an information presentation task for a target user. It does not include any industry specific forms.

3.2 Development Framework/Environment

The INFORMEX development environment needed the ability to represent the presentation formats and content information along with the knowledge that would guide the recommendations. The representation task was well suited to an object-oriented environment [Cox 1986][Stefik and Brobow 1986].

For example, INFORMEX needed to represent pie charts and bar charts as presentation formats in a knowledge base. Intuitively, pie charts are not well suited to presenting a large number of data, however, they are quite useful for presenting the proportional relationship between a smaller number of data. Alternatively, bar charts present an easy way to clearly identify high and low values, and they can logically accommodate more data. While the two presentation formats differ in these ways, they are also similar in a very important way. They both use area as their primary perceptual element and can be classified as an area-based type of graphical chart. Area-based charts share some common properties: They are not well suited to high precision representation (i.e., it is difficult to distinguish between the values of 2.45 and 2.47 on a pie or bar chart), and they are a good way to present summarized data. Through the use of inheritance, an object-oriented (o-o) approach can provide a rich representation environment. Continuing with the preceding example, PIE_CHART and BAR_CHARTS would represent independent objects. Each would be described by a set of attributes such as, complexity rating, maximum number of reasonable display data points, etc. The properties that are common for all area-based objects need not be defined for each object. Instead, a special kind of object called a class is created. A class stores all of the common property values for area-based objects. The PIE_CHART and BAR_CHART objects would be linked to the class AREA-BASED and would automatically inherit all of the common properties of area based presentation formats, unless the object property were assigned a local value unique to that object. To carry the example one step further, LINE-BASED and POINT-BASED are also classes of presentation formats that are linked to other presentation format objects. AREA-BASED, LINE-BASED, and POINT-BASED are all types of graphs and can inherit some of their properties from a higher level class named GRAPHICAL.

In addition to a rich knowledge representation environment, we want INFORMEX to be able to explain its conclusions. It should be able to cite the studies (or other sources used for the development of the knowledge base), experimental environment of the studies, and findings if the INFORMEX user so inquires. The concept of hypertext documents appeared a viable vehicle to provide this information [Fiderio 1988]. Each study has been summarized in a text document that includes the citation, dependent measures, description of the experimental task and subjects, individual-

/cognitive measures, presentation formats that were evaluated, and the findings of the study. For an example of how this works, consider that during an INFORMEX session, INFORMEX recommends that the information be presented in a highly aggregated table format. If a user wants to know about what experiments produced this recommendation, INFORMEX would recall one of the summaries that show highly aggregated tables are well suited to low complexity tasks for either field dependent or field independent types of individuals. By focusing on the word aggregation in the findings section, the user would be chained to all studies that examined level of aggregation. Alternatively, the user could explore why tables were recommended by selecting the word table and linking to the next study about tables.

3.2.1 Development Products

Several expert system shells were evaluated for the INFORMEX prototype. Many of these did not support the object-oriented framework and did not present a suitable representation alternative. Mahogany Professional by Emerald Intelligence was chosen because it supports the o-o environment and provides a rich rule structure.

The Mahogany rule structure is based on an

IF *some set of conditions is True*

THEN *a hypothesis is confirmed or assignments are made*

The IF portion of the rule supports deep conditions and pattern matching. For example, if the user has indicated that presentation precision is important, an IF statement might check for all objects (presentation formats) that have a high precision accuracy. Rather than checking the accuracy property of each object separately, the statement

IF *<graphical.precision> is greater than or equal to 4*

would identify all graphical types of objects with the ability to display data in a highly precise manner. The THEN portion of the rule structure is also very powerful. It allows for the creation of new objects, object property assignments, and the fulfillment of inference goals. Figure 3 contains sample INFORMEX rules.

Several professional hypertext systems were also evaluated. The more pure hypertext products required manual creation of the links between the textual documents. Though these products were quite elegant in design, the manual linking along all of the possible threads (all of the independent variables and findings in the

```
RULE #2 priority 30 - CrS27
 IF -----------------------------
    (1)      the task action is comparison [threshold 0.20]
    (2) and the task complexity is "1 variable" [threshold 0.20]
    (3) and the task structure is structured [threshold 0.20]
 THEN ---------------------------
    (1)      grouped bar chart recommend is yes [certainty 1.00]
    (2) and simple bar chart recommend is yes [certainty 1.00]
    (3) and three d chart recommend is no [certainty 1.00]

RULE #3 priority 30 - Was32
 IF -----------------------------
    (1)      the task type is intellective [threshold 0.21]
    (2) and the task action is comparison [threshold 0.20]
    (3) and the task complexity is "2 variables" [threshold 0.20]
    (4) or  the task complexity is "more than 2 variables" [threshold 0.20]
    (5) and the task structure is structured [threshold 0.21]
 THEN ---------------------------
    (1)      grouped bar chart recommend is yes [certainty 0.60]
    (2) and simple bar chart recommend is yes [certainty 0.60]

RULE #8 priority 50 - find candidate presentation format objects
 IF -----------------------------
    (1)      the report format recommend is yes [threshold 0.20]
 THEN ---------------------------
    (1)      presentation format recommendations is objectname(<report format>) [certainty 1.00]
    (2) and presentation format  is done [certainty 1.00]
```

Figure 3. Sample INFORMEX Rules

29 studies) proved too tedious. INFORMEX needed a text retrieval system that could automatically link the similar terminology between the studies. A product named Minds from Terra Inc. was selected to drive the explanation facility. It has the ability to automatically link all of the studies based on similar performance measures, task environments, individual characteristics, presentation formats, or findings. Any key word can be quickly located in all relevant studies.

3.3 Statistics of the Knowledge Base

The INFORMEX knowledge base consists of 73 rules. Most of these rules have three to six conditions that lead to inferences about presentation format and content. The possible format and content recommendations are represented in 34 objects with the inheritance characteristics described in the previous section. The findings of some studies were very explicit and allowed the rules to make a specific recommendation, i.e. vertically grouped bar charts as a change from a base case. Many studies, however, only lead to a general inference such as area-based format with summary data. This weaker inference suggests that any area-based format (pie, bar, stacked bar) is an eligible recommendation candidate.

Since different studies sometimes produced conflicting results, the rule's certainty factors provide additional insight about the strength of the recommendation. For example, a given set of conditions (intellective task requiring comparison and recall for high analytics) might recommend with .85 certainty that area-based formats are appropriate, while at the same time recommending with a .65 certainty that tables should be used.

3.4 Sample Sessions

This section will describe two sample sessions for INFORMEX. The first session, Figure 4, will follow the approach of a well prepared consultation where most of the answers to INFORMEX's questions are available. This session will pursue a recommendation for a well defined intellective task for a middle manager:

The second sample session, Figure 5, will inquire about a planning task with little knowledge about the individual factors of the user:

3.4.1 Interpretation of Sample Sessions

Though there is some support for several presentation formats and content recommendations, the higher certainty factors point to simple bar charts presented as a change from a base case for session one. INFORMEX also suggests that this information user will not want a large volume of information. This is indicated by 'information user information request' is low finding. Though raw data as the mode of presentation content also has almost equal support to change from a base case (.99 versus 1.00), the information request is low suggests that some level of summarization is recommended.

Session 2 conclusions are less exact than session 1. While tables are clearly not appropriate (certainty = .50), four formats received a certainty rating of .99 and five other formats have a .89 rating. A more careful examination reveals that the four highest ranking formats use a line as their primary perceptual element. The presentation content recommendation was again changed from a base case. No conclusion was available for the 'information user information request' volume.

Question	Response
What is the task type?	intellective
What is the task action?	comparison, retrieval
What is the task complexity?	2 variables
User's cognitive complexity?	field dependent
User's functional knowledge?	medium
Which presentation formats is the user most familiar with?	tabular
User's cognitive type?	unknown
What is the task structure?	structured
What is the ask environmental complexity?	medium

The conclusions from this session follow:

* * * * * * * CONCLUSIONS * * * * * * * *

the information user information request
is low [certainty 1.00]

the presentation format recommendations
is table [certainty 0.64]
is scatter plot chart [certainty 0.71]
is three d chart [certainty 0.70]
is segmented bar chart [certainty 0.80]
is line chart [certainty 0.79]
is area chart [certainty 0.80]
is simple bar chart [certainty 1.00]
is grouped bar chart [certainty 0.70]
is star chart [certainty 0.70]
is pie chart [certainty 0.70]
is column chart [certainty 0.70]

the presentation content recommendations
is change from base case [certainty 1.00]
is raw data [certainty 0.99]
is statistical transformation [certainty 0.80]

* * * * * * * CONCLUSIONS * * * * * * * *

Figure 4. Sample Session 1

4. SUMMARY AND CONCLUSIONS

Developing INFORMEX's knowledge base from a broad group of research findings has proven to be a difficult task. The inconsistencies in terminology and results of the studies greatly complicated the knowledge building process. Yet, even given these

Question	Response
What is the task type?	planning
What is the task action?	trend identification and find relationships
What is the task complexity?	more than 2 variables
What is the task structure?	user-defined
User's cognitive style?	unknown
User's functional knowledge	high
User's cognitive complexity	unknown
Which presentation format is the user most familiar with?	unknown
User's cognitive type	unknown
What is the ask environmental complexity?	high

The conclusions from session #2 follow:

* * * * * * * C O N C L U S I O N S * * * * * * * *

the information user information request
(no values)

the presentation format recommendations
is table [certainty 0.50]
is scatter plot chart [certainty 0.89]
is three d chart [certainty 0.99]
is segmented bar chart [certainty 0.99]
is line chart [certainty 0.99]
is area chart [certainty 0.99]
is simple bar chart [certainty 0.87]
is grouped bar chart [certainty 0.89]
is star chart [certainty 0.89]
is pie chart [certainty 0.89]
is column chart [certainty 0.89]

the presentation content recommendations
is change from base case [certainty 1.00]
is raw data [certainty 0.85]
is statistical transformation [certainty 0.83]

* * * * * * * C O N C L U S I O N S * * * * * * * *

Figure 5. Sample Session 2

obstacles, INFORMEX has demonstrated that rule based expert systems can be used as the knowledge vehicle for research findings. The development of the rule worksheet was a key factor in successfully extracting meaningful rules from the studies.

Though INFORMEX's recommendations are sometimes less conclusive than a user might like, i.e., a recommendation of both tables and graphs with close certainty weights, this is a true reflection of the state of research in this field for some task and individual factor combinations. This project has demonstrated the ability of knowledge based systems to integrate the results from several studies in a research area.

Classifying the existing research in the presentation question field by task, individual factors, presentation format and content, and dependent measures has been a second benefit of this project. This classification and review of the literature has identified areas where little or no research has been performed.

5. FUTURE DIRECTIONS FOR INFORMEX

We are designing an empirical test to assess the validity of INFORMEX's recommendations. The nature of expert systems requires that the knowledge base for INFORMEX will continue to be refined and grow as new knowledge about information presentation becomes available. And considering that the presentation question is a fertile research area, new and more methodologically precise studies will continue to refine our understanding of this area.

In its present infant stage, INFORMEX could be used as a training tool for information analysts. By entering various combinations of responses to user and task demands, information system professionals could be more enlightened about the presentation needs and preferences of their clients. Ideally, future versions of INFORMEX will be an embedded part of a company's MIS. User cognitive profiles could be retained in a database as well as task classifications for various recurring types of managerial activities. A systems analyst would consult INFORMEX and simply identify the target user and type of activity that the information will be used for. Since the answers to many of INFORMEX's questions would be available in a database, system consultation time could be greatly reduced. In a truly integrated environment, an end-user could request information from a data base and INFORMEX could direct a report writer to create the report with the format and content most appropriate to the information user. INFORMEX is a first step in that direction.

References

Ackoff, R.L.(1967), "Management Misinformation Systems," *Management Science*, 14, No. 5, (May), 147-156.

Barker, V.E. and O'Connor, D.E. (1989), "Expert Systems for Configuration at Digital: XCON and Beyond," *Communications of the ACM*, 32, No. 3, (Mar.), 298-317.

Chervany, N.L., and Dickson, G.W. (1974), "An Experimental Evaluation of Information Overload in a Production Environment," *Management Science*, 20, (June), 1335-1344.

Cox, B.J. (1986), *Object-Oriented Programming: An Evolutionary Approach*, Addison-Wesley Publishing Company, Reading, MA.

Dickson, G.W., Senn, J.A., and Chervany, N.L. (1977), "Research in Management Information Systems: The Minnesota Experiments," *Management Science*, 23, No. 9, (May), 913-923.

DeSanctis, G. (1984), "Computer Graphics as Decision Aids: Directions for Research," *Decision Sciences*, 15, 463-487.

Edosomwan, J.A. (1987),"Ten Design Rules for Knowledge Based Expert Systems," *Industrial Engineer*, (Aug.), 78-80.

Fiderio, J.(1988), "A Grand Vision," *Byte*, (Oct.), 237-243.

Huber, G.P. (1983), "Cognitive Style as a Basis for MIS and DSS Designs: Much Ado About Nothing?" *Management Science*, 29, No. 5, (May), 567-579.

Jarvenpaa, S.L., Dickson, G.W., and DeSanctis, G. (1985), "Methodological Issues in Experimental IS Research: Experiences and Recommendations," *MIS Quarterly*, (June), 141-156.

Luconi, F.M., Tohmas, W., and Scott Morton, Michael S. (1986), "Expert Systems: The Next Challenge for Managers," *Sloan Management Review*, (Summer), 3-13.

Rauch-Hinden, W.B. (1988), *A Guide to Commercial Artificial Intelligence*, Prentice-Hall, New Jersey.

Rangaswamy, A., Eliashberg, J., Burke, R.R., and Wind, J. (1989), "Developing Marketing Expert Systems: An application to International Negotiations," *Journal of Marketing*, 53, (Oct.), 24-39.

Samson, D. (1989), "Object-Oriented Requirements Definition: Closing the Disconnect," *Proceedings of the 1987 IEEE International Conference on Systems, Man, and Cybernetics*, (Oct.), 217-221.

Sayles, W. and Thomas, J. (1988), "Finding and Fixing Network Faults with an Expert System," *Data Communications*, (June), 149-165.

Stefik, M. and Brobow, D. (1986), "Object Oriented Programming: Themes and Variations," *AI Magazine*, 6, No. 4, (Winter), 40-62.

Vasarhelyi, M.A. (1977), "Man-Machine Planning Systems: A Cognitive Style Examination of Interactive Decision Making," *Journal of Accounting Research*, (Spring), 138-153.

Zmud, R.W. (1979), "Individual Differences and MIS Success: A Review of the Empirical Literature," *Management Science*, 25, (Oct.), 966-979.